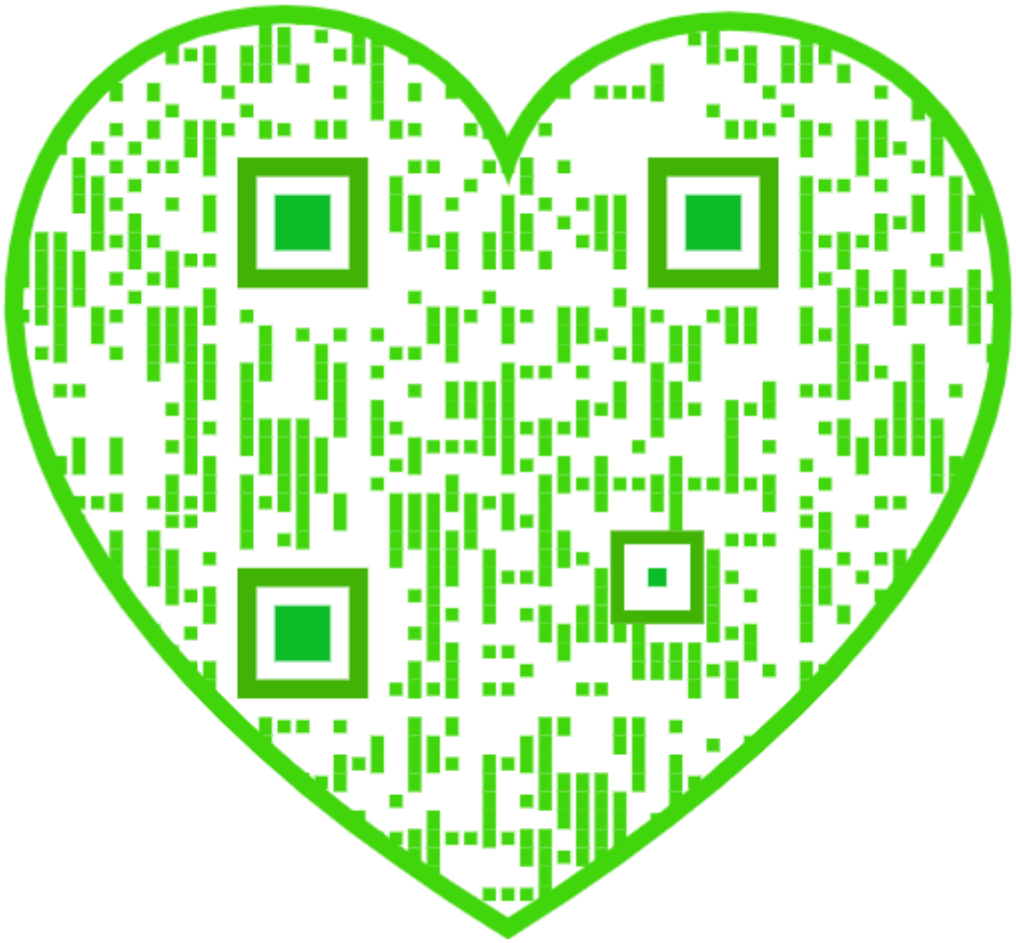

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U. S. COMMISSION OF FISH AND FISHERIES.
GEORGE M. BOWERS, Commissioner.

ARTIFICIAL PROPAGATION

OF THE

ATLANTIC SALMON, RAINBOW TROUT,

AND

BROOK TROUT.

Extracted from the Revised Edition of the Fish Manual. Pages 17 to 90, Plates 11 to 29.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

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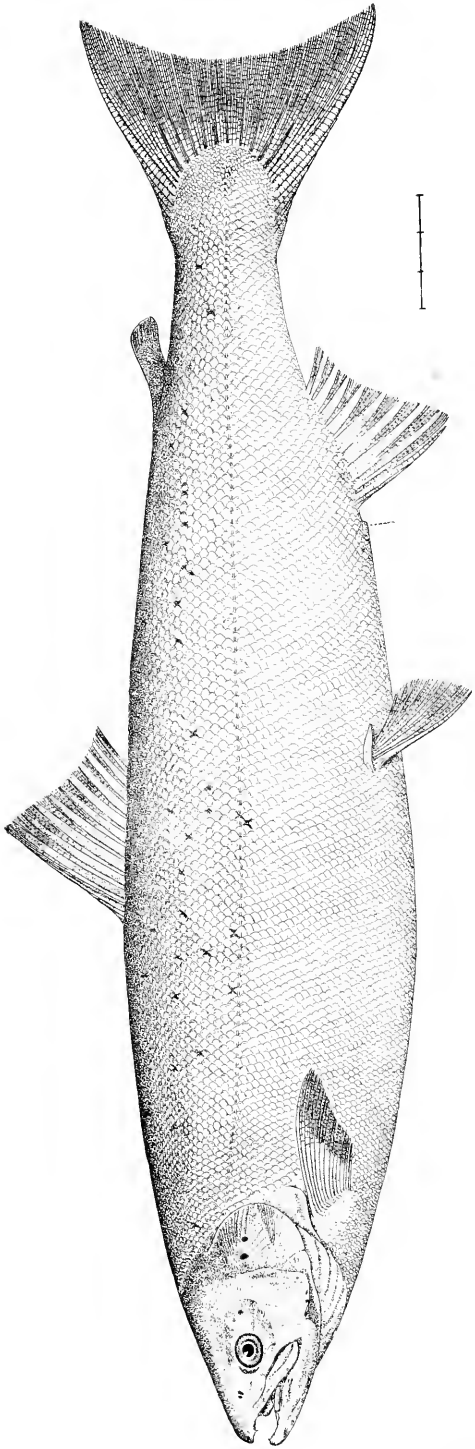


SALMO SALAR. *Atlantic Salmon.*

THE ATLANTIC SALMON

DESCRIPTION OF THE FISH.

The body of the Atlantic salmon (*Salmo salar*) is moderately elongate and but little compressed; the greatest depth is about one-fourth the total length without the caudal fin. The length of the head is about equal to the body depth. The mouth is of moderate size, the maxillary reaching just past the eye, its length contained $2\frac{1}{2}$ or 3 times in the head. The scales are comparatively large, becoming embedded in adult males; the number in the lateral line is about 120, with 23 above and 21 below that line. The dorsal fin has 11 rays and the anal 9 rays. The pyloric cœca number about 65.

The color, like the form, varies with sex, age, food, and condition. The adult is brownish above and silvery on the sides, with numerous small black spots, often x or xx shaped, on the head, body, and fins, and with red patches along the sides in the male. Young salmon (parrs) have about 11 dusky crossbars, besides black and red spots.

RANGE.

The salmon native to the rivers of the northeastern United States is specifically identical with the salmon of Europe and all the affluents of the North Atlantic. Its original natural range in America appears to have been from Labrador or Hudson Bay on the north to the vicinity of New York on the south. Within these limits, at the proper season of the year, it ascended, for the purpose of reproduction, nearly every river except those that did not afford the requisite facilities for depositing spawn or were inaccessible by reason of impassable falls near their mouths.

In American rivers frequented by Atlantic salmon they were found successively in all parts from the mouth upward, their migrations extending nearly to the headwaters of all the branches so far as they were accessible and adapted to their necessities. The one exception is the river St. Lawrence, where it seems probable, from such evidence as is available, that few if any salmon entering the river from the sea ever ascended as far as Lake Ontario, and that the salmon inhabiting that lake and its tributaries have always, as a rule, made the lake their sea and the limit of their downward migrations. Within or partly within the limits of the United States there can be enumerated twenty-eight rivers that were beyond doubt naturally frequented by salmon, beginning with

the St. John and ending with the Housatonic.* In the greater part of these the species has been exterminated by civilized man, and in the few in which it still persists its numbers are far below the estimates which the earliest records warrant us in making for those days.

In certain lakes of Maine and northward this fish is perfectly landlocked and has somewhat different habits and coloration, but no distinct specific characters. Similar landlocked varieties occur in Europe.

LIFE AND HABITS.

Salmon eggs are deposited on coarse gravel on some rapid, generally far up toward the sources of a river, late in October or early in November, when the water is perhaps about 44° F. and the temperature is falling. The egg is impregnated at the moment of its deposit, and the independent life of the salmon begins to develop at once. In a few weeks the embryo becomes sensitive, but the extreme cold of the water retards its development to such an extent that it does not burst the shell of the egg until spring. In the rivers of New England it is probable that nearly all the eggs naturally deposited hatch very late in April and early in May. At this time the embryo salmon has a slender half-transparent trunk, less than an inch in length, carrying, suspended beneath, an immense ovoid sac—the "yolk-sac." For about six weeks after hatching it hides in crevices among stones, keeping up an incessant fanning with its pectoral fins. During this period it takes no food, but is supported and nourished by the yolk-sac, the substance of which is gradually absorbed into the rest of the body, and not until the sac has nearly disappeared does the salmon really look like a fish and begin to seize and swallow food. It now puts on a mottled coat, with several heavy dark bars across its sides, and bright red spots, larger and fewer than those of a trout, looking therefore very unlike the adult salmon but much like a young trout. In this stage it is termed, in Scotland and England, a "parr," and it was formerly thought to be a wholly different species from salmon.

The parr stage lasts a year or two in British rivers, and the few observations made in America indicate that it is more likely two years than one in our rivers. The parr, at first but little over an inch in length, is provided with good teeth and a good appetite, and beginning to feed at a season of the year when the water is almost crowded with small insects and other more minute creatures, it grows rapidly, probably increasing its weight thirty or forty times the first summer. In two years it reaches the length of 6 or 8 inches, and its bright red spots and dark bars have given place to a silvery coat like the adult salmon. It is now termed a "smolt" and is ready to go to sea, which it does with little delay, and passes out beyond the range of man's

* The Hudson River is by some believed to have been a natural salmon river. Its discoverer, Hendrik Hudson, reported having observed them there, and there is nothing inherently improbable in it, but the evidence is perhaps insufficient.

observation, but to a region where it finds a rich feeding-ground and rapidly increases in size.* In northern rivers, those of New Brunswick and beyond, as in those of northern Europe, the salmon returns from the sea when it has attained a weight of 2 to 6 pounds, and is then termed a "grilse."

In the rivers of Canada, in general, grilse occur in great numbers, coming in from the sea at a later date than the adults, but ascending like them to the upper waters, mingling freely with them, rising to the same fly, and caught in the same weirs. The mesh of the nets is limited by law to a size that takes the adult salmon, but allows the grilse to slip through. To this circumstance it is in part owing that by the time the fish have reached those portions of the rivers suitable for angling there is commonly, if it be late enough in the season, a great preponderance of grilse, so that more of the latter than of the former are taken by the angler. In Nova Scotia many grilse are taken in the Shubenacadie River from August until late in the fall. On the Miramichi, in New Brunswick, grilse make their appearance about July 1, and from the middle of that month till the end of August they constitute the main body of the salmon entering the river. Some sportsmen report that the grilse caught exceed the adults in the ratio of 5 to 1.

In the month of August, in the Nepissiguit, Restigouche, and St. John of Gaspé, grilse have been found in some years to exceed the adults in the ratio of 3 to 1. They run into the Nepissiguit mostly between July 25 and September 1. Their scarcity during the early part of the angling season, or say previous to July 20, is attested by numerous fishing scores. A series of scores of salmon fishing in the Godbout River, on the north side of the St. Lawrence, shows that previous to July 15 or 20 the adult salmon taken with the fly in that river exceed the grilse in the ratio of 10 to 1 or more.

In our rivers grilse are seldom seen, and only 3 or 4 are taken per year in a weir in the St. Croix, which takes about 70 adults. In the Dennys River the ratio of grilse to salmon caught is not more than 1 to 500, and in the Penobscot they are quite as rare. Adult salmon running in this river several weeks earlier than in those of eastern New Brunswick, we

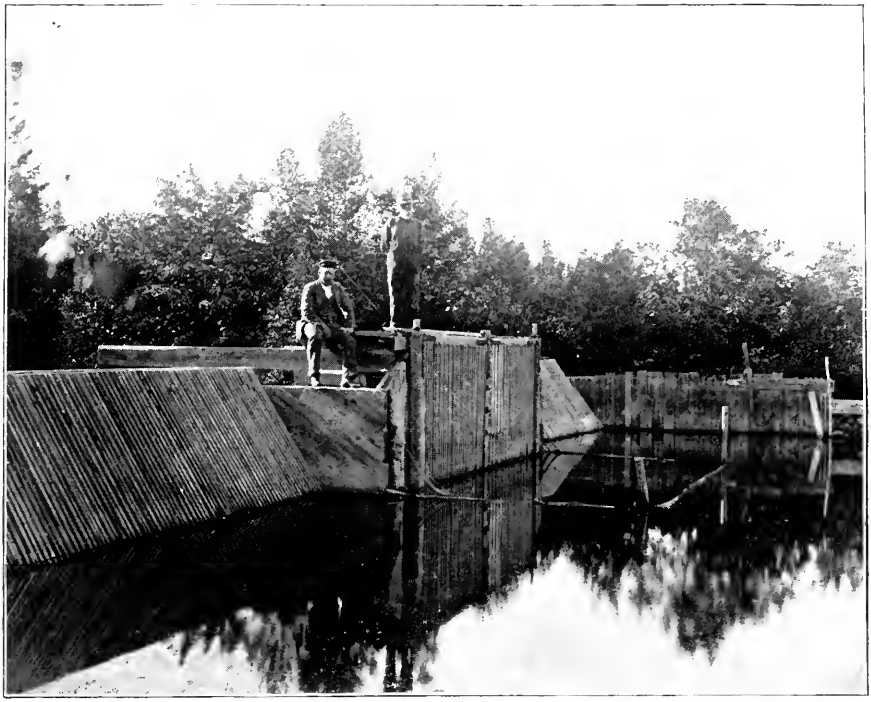
*There has been considerable discussion on this point, and the conclusions of some observers are at variance with the above statement. In Scotland many years ago it seemed to be well established by the observations of Buist that a portion of the young salmon put on the silvery coat and went to sea at the age of one year, but that others of the same brood did not get ready to go until two years old. American observations, however, tend strongly to the conclusion that the young salmon passes two whole summers in the river, going out to sea in the autumn following its second summer or the next spring. It is not probable that the seaward migration is restricted in any river to any exact period of a few weeks duration, but that it extends over many months, some of the young salmon, by reason of superior native vigor of growth or from other equally efficient cause, attaining the migratory stage months earlier than others of the same brood.

It is the opinion of one American observer that salmon fry remain in the streams until October of the second year before going to sea, and that they do not go down until the spring of the third year; i. e., when they are two years old; though some may go down the fall of the second year; and that the salmon do not return until they are four years old.

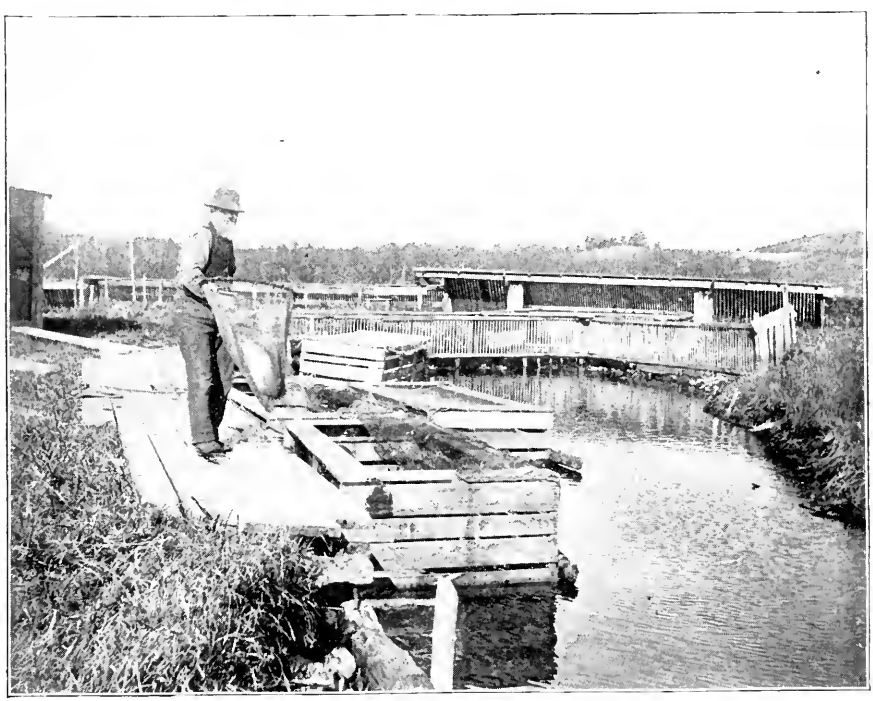
should naturally expect the advent of grilse early in July in considerable numbers; but some of the weirs are often kept in operation until the middle or last of July, and sometimes even through August, when they take menhaden; but no grilse enter them. During the latter part of the summer the water at the several falls between Bangor and Oldtown is generally at a low stage, and the attempt of grilse, even in small numbers, to ascend the river could hardly fail to be frequently detected. A similar state of things exists in the Kennebec. There is no escaping the conclusion that the great run of grilse, which is so prominent a feature in the history of the salmon of northern rivers, is almost entirely wanting in the rivers of the United States. It by no means follows from this that our salmon do not pass through the same phases of growth, or that the growth is more rapid, but merely that when in the grilse stage they generally lack the instinct that impels their more northern relatives to seek fresh water.

Of the characteristics of grilse, as ascertained in the rivers they frequent, it will be sufficient to say that they exhibit to a great degree the characteristics of the adult; that the main external differences are a shorter head, slenderer form, and a difference in the color and markings; that they are remarkably active and agile, leaping to great heights; that the male is sexually well developed and mates with the adult, but that the female is immature, and that, like the adult, they abstain from food and consequently lose flesh during their stay in fresh water.

The next stage of life of the fish is that of the adult salmon, and this is the stage at which, with the exceptions indicated above, the Atlantic salmon first ascends the rivers of the United States. Assuming that it relinquished the rivers for the sea at the age of two years, being then a smolt, it has been absent two years, and it is now four years or a little more since it burst the shell. This estimate of age is based on the observations made by the Massachusetts commissioners of fisheries on the return of salmon to the Merrimac River, which plainly established the fact that the entire period between the hatching of the fry and the return of the adult to the rivers is about four years. Whether the same rule holds in other New England rivers can not as yet be established, owing to deficient data, but the presumption is in favor of that conclusion. In Canadian rivers the same period of growth appears to be the universal rule, at least as far north as the St. Lawrence River. Statistics of the catch of salmon for many years in eighteen separate districts, showing many fluctuations, exhibit a remarkable tendency of the figures to arrange themselves in periods of five years; thus, the year 1875 having been a year of small catch of salmon, it also appears in most of the districts that the next year of abnormally small catch was 1880. Now, the eggs laid in 1875 would hatch in 1876, and the young hatched at that time would be grown in 1880, requiring thus four years from hatching to maturity, just as on the Merrimac. It would seem no other interpretation can be put upon the statistics.



ENTRANCE TO DEAD BROOK INCLOSURE FOR SALMON.



DEAD BROOK INCLOSURE FOR ATLANTIC SALMON, SHOWING PENS.

EARLY SALMON-CULTURE ON THE PENOBSCOT RIVER.

The movement for the reestablishment of the fisheries for salmon, shad, and other anadromous species in American rivers originated in the action of the legislatures of New Hampshire and Massachusetts, having in view primarily the fisheries of the Merrimac and Connecticut rivers. The course of the Connecticut lies partly in the State of Connecticut, while many of its tributaries are in the State of Vermont, and these two States were therefore early interested in the project, and their action soon led to a similar movement on the part of Rhode Island and Maine. The rivers within the borders of these six States are the only ones in the United States known to have been frequented by the seagoing *Salmo salar*, except possibly the Hudson and certain rivers tributary to the St. Lawrence, in the northern part of New York.

The commissioners to whom the governments of the above States confided the task of restocking the exhausted rivers turned their attention at once to the two most important of the migratory fishes, the salmon and the shad. The utter extermination of salmon from most of the rivers compelling the commissioners to consider the best mode of introducing them from abroad, eggs were obtained for a time from the spawning-beds in the rivers of Canada and hatched with a measure of success. After a few seasons permits for such operations were discontinued, and it became essential to look elsewhere for a supply of salmon ova. In 1870 attention was directed to the Penobscot River, in the State of Maine, which, though very unproductive compared with Canadian rivers, might yet, perhaps, be made to yield the requisite quantity of spawn. The fisheries are all in the lower part of the river and in the estuary into which it empties, Penobscot Bay, and there the supply of adult salmon could be found with certainty, but they must be obtained from the ordinary salmon fisheries in June and held in durance until October or November, and the possibility of confining them without interfering seriously with the normal action of their reproductive functions was not yet established.

This plan was finally adopted, and in 1871 this method of breeding salmon was first attempted. For the purpose of the experiment, a point at the mouth of Craig Brook, which is by water nearly 9 miles distant from the mouth of the Penobscot River, more than half the route being through brackish water, was selected as the most convenient fresh-water stream which offered facilities for confining the salmon and maturing their eggs. After some unsuccessful trials means were found of safely conveying a few live salmon in floating cars from the fishing-grounds to the station, where they were held till the spawning season, when their eggs were taken and impregnated.

From 1872 to 1876 operations were conducted on a larger scale, with a fair degree of success, and, after a suspension, were resumed in 1879 at Craig Brook hatchery, while the retaining inclosures were located in Dead Brook, about 2 miles distant. The disadvantage of this

distance between the hatchery and retaining-ponds was offset by other advantageous conditions.

Until 1886 no attempt was made to rear salmon, and with unimportant exceptions the work was confined to the collection of salmon eggs, their development during the earlier stages, and their transfer in winter to other stations to be hatched. In 1889, however, the United States Fish Commissioner decided to establish a permanent station at Craig Brook, and in anticipation of the purchase of the premises, which was concluded the following year, the rearing of salmon to the age of six or seven months was undertaken as the leading work of the station.

WATER FOR A SALMON HATCHERY.

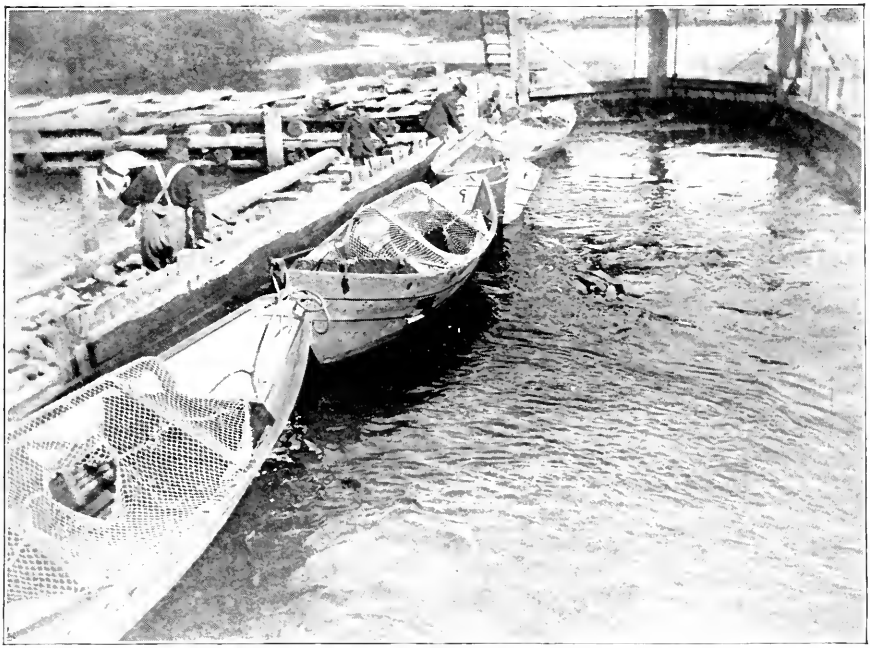
The first requisite for a salmon hatchery is an ample supply of suitable water, on a site where it can be brought completely under control and the requisite fall secured. In this matter there is quite a range of choice. The very best is the water from a stream fed by a clean lake of considerable depth, taken a short distance below the outlet of the lake, with an intervening rapid. Craig Pond may be taken as an example of such a lake. It has an area of 231 acres, an extreme depth of 69 feet, and a depth of 25 feet within 500 feet of the outlet. The depth directly influences the temperature and, other things being equal, a deep lake will afford water more uniform in temperature than a shallow one—cooler in summer and warmer, though never too warm, in winter. Such water is commonly quite even in volume and temperature, and comparatively pure. It is cold in winter and warms up slowly in spring, assuring a slow, normal development of the eggs, which is more conducive to health and vigor than a quicker development. The passage down a rapid will further improve this water by charging it highly with air.

After this, the water of a brook is to be chosen that is fed largely by springs, so as to insure constancy in the supply and some moderation of the temperature on warm days, but it is better to have the water flow a long distance in an open channel before using, and, if possible, over a rough and descending bed, that it may be well aerated, and in cold weather somewhat cooled down from the temperature with which it springs from the ground.

The next best is pure spring water; but in all cases where this is used a cooling and aerating pond is necessary, that the original warmth of the water may be subdued by the cold of the air before it reaches the hatching-troughs, and that it may absorb more or less air by its wide surface.

Lastly, choose ordinary river or brook water, as clean as possible. These are inferior to spring water by reason of liability to floods, drought, muddiness, and foulness of other sorts, and in cold climates to anchor ice.

Between these different sorts there is of course an infinite number of gradations. If lake water can not be obtained it would be of some



SALMON LIVE-CAR USED IN TRANSPORTING FISH FROM WEIRS TO DEAD BROOK.

SALMON LIVE-CARS EN ROUTE WITH FISH.

advantage to have a supply of both spring water and brook water, depending for ordinary use on the brook water or a mixture of the two, and on the spring water for emergencies, such as the freezing, drying, or excessive heating of the brook, floods with accompanying muddiness, etc. Water coming from boggy and stagnant ponds and marshes is objectionable; for though excellent water, capable of bringing out the most vigorous of fish, may sometimes be had in such places, yet when not supplied by springs it is dependent for its freshness and good qualities on rainfalls, and if these fail, as they are liable to, the water may become foul and unfit. It must be borne in mind that these remarks about the selection of water for fish-cultural purposes apply only to the culture of Atlantic or landlocked salmon, in a climate like that of the State of Maine.

It is best to select a site for a hatching establishment in time of extreme drought, and if it then has an ample supply of pure, sweet water the first requisites are fulfilled. It is well also to visit the place in time of flood and, if in a cold climate, in severe winter weather, to learn the dangers to be guarded against on those scores. The volume of water necessary will depend mainly on the proposed capacity of the establishment, the temperature of the water, its character as to aeration, and the facilities existing for the aeration and repeated use of the water. With water of the highest quality and low temperature, and with unlimited facilities for aeration, possibly a gallon a minute, or even less, can be made to answer for the incubation of 100,000 eggs of salmon. As the temperature rises or the facilities for aeration are curtailed a larger volume becomes necessary. In case of spring water, cooled only to 40° and aerated only by exposure to air in a pool of about a square rod surface, with no facilities in the house for aeration, and with the eggs and fry crowded in the troughs at the rate of 4,000 per square foot, 4 gallons a minute is the least that can be allowed, while 6, 8, or 10 gallons per minute are better. While the minimum is, as stated above, possibly less than a gallon a minute, it is not advisable to trust to less than 3 gallons per minute for each 100,000 eggs under the most favorable circumstances.

If the water supply is drawn from a small brook or spring, it is necessary to measure the volume approximately, which is easily done, in the following manner: With a wide board 1 inch thick, having a smooth inch hole bored through the middle, a tight dam is made across the stream so that all the water will have to flow through the hole. If the water on the upper side rises just to the top of the hole, it indicates a volume of 2.3 gallons per minute; a rise of half an inch above the top of the hole indicates a volume of 3.5 gallons per minute; 2 inches rise, 5 gallons per minute; 3 inches, 6 gallons per minute; 6 inches, 8 gallons per minute; 13 inches, 12 gallons per minute. If two 1-inch holes are bored, the same will, of course, indicate twice the volume. The volume of water flowing through holes of different sizes is in proportion to the

squares of their diameters; thus a 2-inch hole permits the passage of four times as much as a 1-inch hole. A tube whose length is three times its diameter will allow 29 per cent more water to pass than a hole of the same diameter through a thin plate or board.

SITE.

After a satisfactory supply of water is found a site for the hatching-house must be selected that affords facilities for creating a head of water to provide for the requisite fall into and through the troughs, security against inundation, security against too much freezing if in a cold climate, and, finally, general safety and accessibility. The fall required in the hatching-house can hardly be too great. The minimum is as low as 3 inches, but only under the most favorable circumstances in other respects will this answer, and even then it is only admissible where there is an ample supply of aerated water and the troughs are very short and there is absolutely no danger of inundation; and this fall has the disadvantages of the impracticability of introducing any aerating apparatus and the necessity of having the troughs sunk below the floor of the hatching-house, which makes the work of attending the eggs and fish very laborious.

A fall of 1 foot will do fairly well if there is entire safety from inundation, as this will permit the troughs being placed on the floor, which is a better position than below it, though still an inconvenient one, and some of the simpler aerating devices can be introduced. Better is a fall of 3 feet, and far better a fall of 6 feet. The latter permits the placing of the lowest hatching-troughs 2 feet above the floor and leaves ample room for complete aeration. The necessities of the case are dependent largely upon the volume and character of the water, and if there is plenty of it, well aerated before reaching the hatching-house, there is no occasion, in a small establishment, of additional aeration in the house, and therefore no need of more than 3 feet fall.

Inspection of the premises at time of floods will suggest the safeguards necessary to provide against inundation. If located by a brookside, the hatching-house should not obtrude too much on the channel, and below the house there should be an ample outlet for everything that may come. By clearing out and enlarging a natural watercourse much can often be done to improve an originally bad site.

In a cold climate it is an excellent plan to have the hatching-house partly under ground, for greater protection against outside cold. When spring water is used there is rarely any trouble, even in a cool house, from the formation of ice in the troughs; but water from lake, river, or brook is, in the latitude of the northern tier of States, so cold in winter that if the air of the hatching-house is allowed to remain much below the freezing-point ice will form in the troughs and on the floor to such an extent as to be a serious annoyance, and if not watched will form in the hatching-troughs so deeply as to freeze the eggs and destroy

them. Stoves are needed in such climates to warm the air enough for the comfort of the attendants; but the house should be so located and constructed that it may be left without a fire for weeks without any dangerous accumulation of ice, and if the site does not permit of building the house partly under ground the walls must be thoroughly constructed and banked well with earth, sawdust, or other material. In warmer climates no trouble will be experienced from this source.

DAMS AND CONDUITS.

The requisite head of water can often be had by throwing a dam across the stream and locating the hatching-house close to it. The dam will form a small pond which will serve the triple purpose of cooling, aerating, and cleansing the water. But unless the bed and the banks of the stream are of such character as to preclude any danger of undermining or washing out the ends of the dam, it is best not to undertake to raise a great head in this way. With any bottom except one of solid ledge there is always great danger, and to guard against it when the dam is more than 2 feet high may be very troublesome. If there is a scarcity of water, or if it is desirable, for aerating or other purposes, to secure a considerable fall, it is better to construct the dam at some distance above the hatching-house, on higher ground, where a very low dam will suffice to turn the water into a conduit which will lead it into the hatching-house at the desired height.

A square conduit made of boards or planks, carefully jointed and nailed, is in nearly all cases perfectly satisfactory, and for an ordinary establishment a very small one will suffice.

The volume of water that will flow through a pipe of a given form depends upon its size and the inclination at which it is laid. A straight cylindrical pipe, 1 inch in diameter, inclined 1 foot in 10, conveys about 11 gallons of water per minute. The same pipe, with an inclination of 1 in 20, conveys 8 gallons per minute; with an inclination of 1 in 100, it conveys 3½ gallons per minute; with an inclination of 1 in 1,000, it conveys 1 gallon per minute. A 2-inch pipe conveys about 5½ times as much water as an inch pipe; a 3-inch pipe nearly 15 times as much. A 1-inch pipe, with an inclination of 1 in 1,000, conveys water enough for hatching 25,000 eggs; with an inclination of 1 in 50, enough for 100,000 eggs; with an inclination of 1 in 20, enough for nearly 200,000 eggs. A square conduit conveys one-quarter more water than a cylindrical pipe of the same diameter. If there are any angles or abrupt bends in the pipe, its capacity will be considerably reduced. It should be remembered that if the water completely fills the aqueduct it is entirely shut out from contact with the air during its passage, whereas if the pipe is larger than the water can fill, the remainder of the space will be occupied by air, of which the water, rushing down the incline, will absorb a considerable volume and be greatly improved. It is therefore much better to make the conduit twice or thrice the size

demanded by the required volume of water. If the bottom and sides are rough, so as to break up the water, so much the better, and the wider the conduit is the more surface does the water present to the air.

AERATION.

The water which fishes breathe is but the medium for the conveyance of air, which is the real vivifying agent, without which fish and eggs will die, and with a scanty supply of which the proper development of the growing embryo is impossible. Water readily absorbs air whenever it comes in contact with it, and the more intimate and the longer continued the contact the greater the volume it will absorb. The ample aeration of the water to be used in the hatching-house has already been mentioned as a desideratum of the first importance, and some of the devices by which it is to be secured have been alluded to.

Water from either a brook or a river that has been torn into froth by dashing down a steep bed has absorbed all the air that is needed in 10 or 20 feet of hatching-trough, and demands no further attention on this score; but if the water is taken from a lake, a spring, or a quiet brook it contains less air, which may be so reduced before it gets through the hatching-house as to be unable to do its proper work. It is therefore desirable to adopt all practicable means of reinforcing it. If the site of the hatching-house commands a fall of 5 feet or more, the object may be attained by contriving in the conduit outside the house, or in the hatching-troughs themselves, a series of miniature cascades.

The broader and thinner the sheet of water the more thoroughly it is exposed to the air, and if, instead of being allowed to trickle down the face of a perpendicular board, it is carried off so that it must fall free through the air, both surfaces of the sheet are exposed and the effect is doubled. When circumstances permit, it is best to aerate in the conduit, which, as already suggested, may be made wide and open for that purpose.

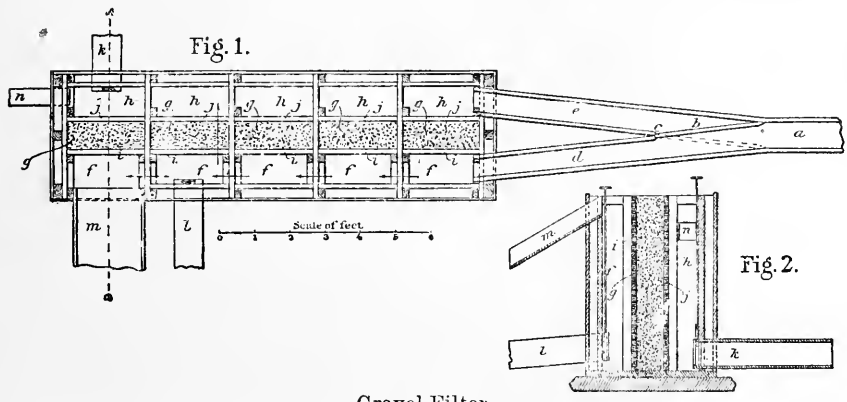
If aeration can not be effected outside the house it may be done inside by arranging two long troughs side by side, leveled carefully, so that the water is received in one of them and poured over into the other in a sheet the whole length of the trough. In the hatching-troughs themselves there is an opportunity for aeration, either by making short troughs with a fall from one to another or by inclining the troughs and creating falls at regular distances by partitions or dams, each with its cascade, after the fashion already described. The only serious difficulty is encountered where the ground is very flat, so that the requisite fall can not be obtained, and in this case the best that can be done is to make a very large pool, several square rods at least, outside the house, and make all the conduits as wide as possible, so that the water shall flow in a wide and shallow stream.

It will of course be borne in mind that the better the aeration the smaller the volume required to do a given work, and on the other hand

it is equally true that the greater the volume the less aeration is necessary. When so large a volume as 6 gallons per minute for every 100,000 eggs is at command, a comparatively small amount of aeration will answer. But, so far as known, the higher the degree of aeration the better the result, without limit, other things being equal, and it is therefore advised to make use of all the facilities existing for this purpose.

FILTERING.

Before the introduction of wire or glass trays for hatching fish eggs it was customary to lay them on gravel, and it was then absolutely necessary to filter all but the purest water. Even ordinary spring water deposits a very considerable sediment, which might accumulate upon the eggs to such an extent as to deprive them of a change of



Gravel Filter.

a, conduit from brook.
b, gate, swinging on pivot at *c*, to change direction of water.
d, direct branch of conduit.
e, reverse branch of conduit.
f, *f*, *etc.*, a single long compartment for unfiltered water.
g, *g*, *etc.*, compartments occupied by gravel.
h, a single long compartment for filtered water.
i, *j*, racks to hold gravel in place.
i is in 5 sections, movable, and can be taken out when gravel is to be renewed.
k, *l*, sluices near bottom for cleaning out.
m, wasteway.
n, aqueduct to hatchery.

water and smother and destroy them. When, however, eggs are deposited on trays arranged for a circulation of water beneath, as well as over them, as described below, even though their upper sides are covered with sediment, they are clean and bright underneath and remain in communication with the water beneath the tray, though of course the circulation of the water through the tray is not perfect. It is not, therefore, deemed necessary to introduce any considerable devices for filtering water which is naturally very pure, like lake and spring water when not subject to intermixture with surface water during rains; but where it is necessary to use water subject to constant or occasional turbidness some method of filtering is indispensable.

In the majority of cases at least a portion of the water supply is obtained from an open brook, lake, or pond, and measures must be taken

to get rid of the leaves and other coarse rubbish brought down by the stream or conduit. A great deal of such material is encountered in a stream at all seasons of the year, but during the fall and early winter it is especially abundant, and to secure entire safety from a stoppage of the water, and consequent loss, a screen on a generous scale must be provided.

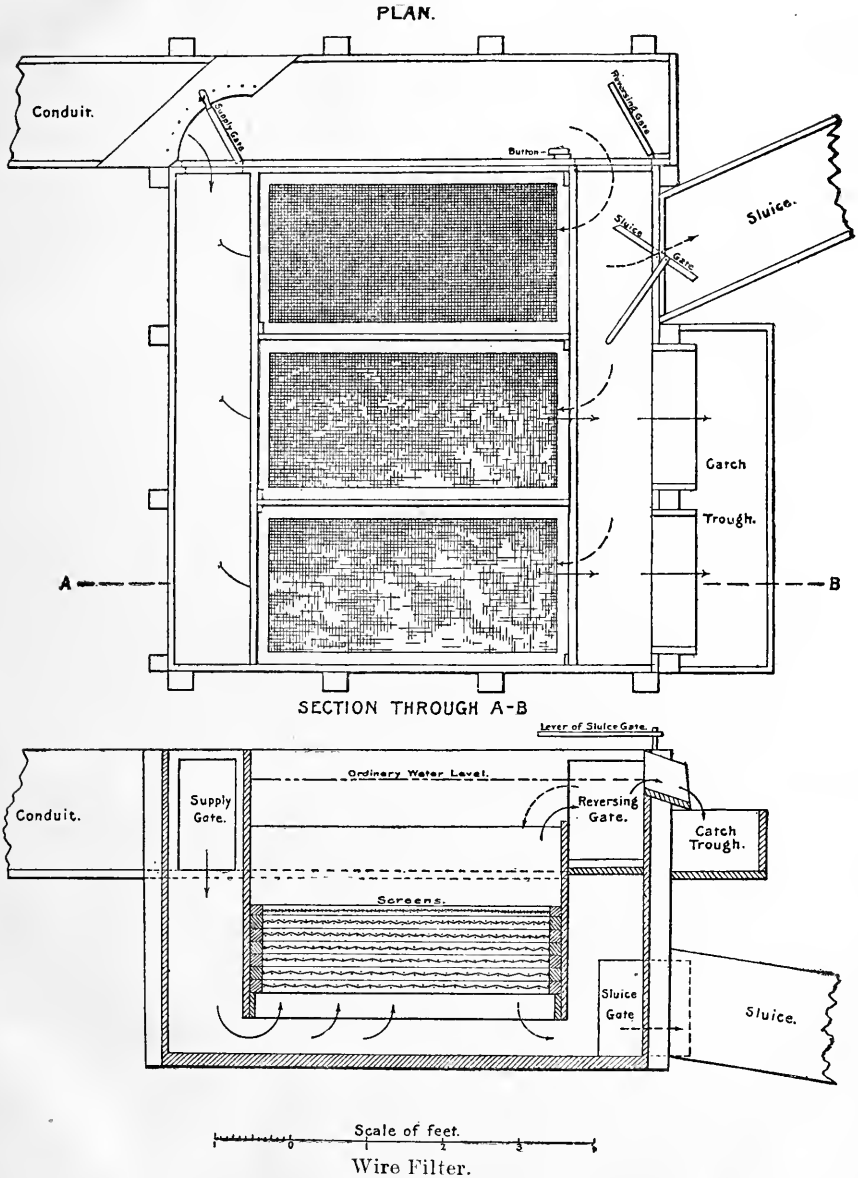
A description of the means adopted at this station for providing a temporary extra water service of several hundred gallons per minute, taken from Craig Brook, will serve as an illustration: A tank or vat, 12 feet square and about 2 feet deep, is built in the bed of the brook with a tight dam of stones, gravel, loam, and leaves (these to stop small leaks) running ashore on either side, so that the entire volume of the brook passes over the tank. The bottom and sides are tight and strong, and both bottom and top are inclined about 6 inches down the stream. The cover is of spruce lumber sawed 1½ inches square and nailed on in the direction of the current, with interstices open half an inch; when in operation the water fills the tank and runs over the lower edge, which is raised enough to maintain a depth of several inches over nearly the whole tank. All leaves and other materials floating near the surface of the water are carried over, together with most rubbish which floats deep. At one of the lower corners of the tank, near the bottom, is a gate about 15 inches square, which is hung by hinges on its upper side. It opens inward, and is closed tightly by the pressure of the water; but it can be easily opened by pushing with a pole from without, and then serves as a floodgate, whereby the tank may be thoroughly cleaned out.

At the other lower corner is a conduit, 6 by 9 inches, which takes from this "leaf-screen" a supply of water not entirely free from rubbish, but so nearly so that a filter of moderate capacity can cope with what remains. A very useful adjunct would be a second horizontal screen of similar construction, through which the water that has passed downward through the first screen, as described, should next pass upward through the second; the first screen would remove floating débris, the second such as is heavier than water.

The filter, situated about 70 feet from the leaf-screen, consists of a wooden flume, 12 feet long and 4 feet deep, divided lengthwise into three compartments, of which the central contains fine gravel held in place by a rack on either hand, of which the interstices are ½ inch wide and 1½ inches apart. The water from the leaf-screen is introduced into one of the lateral compartments, and filters through the gravel into the opposite compartment, from which it is taken by a plank aqueduct, 6 by 6 inches, to the hatchery. Under the conditions described, and with a fall of about 1 foot from supply to discharge, this filter discharges over 300 gallons of water per minute into the aqueduct—water not absolutely pure, but sufficiently free from coarse dirt for the purpose.

In many cases, where small quantities of water are used, it is custo

mary to filter through flannel screens in the hatchery, and such filters do very good service. They can be introduced into the egg-troughs, or by running them lengthwise of a trough a very large volume of water can be filtered.



Wire Filter.

A form of filter that has given good satisfaction at the Craig Brook station through five years of service consists of a series of graduated wire screens, through which the water passes upward, first through the coarser and then through the finer screens, with provision for the

reversal of the current for cleaning purposes. By reference to the cut on page 29, it will be seen that the water is brought to the filter through a plank conduit, and is admitted to the filter through either of two gates that swing on hinges, one for the direct flow and the other for the reversal. The direct flow is first into a receiving chamber, which extends under the screens, then upward through the whole series and out at the top, overflowing into a catch-trough, from which it is distributed as desired. In cleansing, the supply-gate is closed and the other one opened, and at the same time the sluice-gate at the bottom is opened; the water then flows in full volume upon the screens and down through them, carrying all the intercepted débris into the lower chamber and out through the sluice-gate.

The wire filter illustrated has to pass some 500 gallons of water per minute, and has three screen-boxes, each of which carries 5 to 7 screens about 2 feet wide and 4 feet long; the meshes are from 2 inches down to $\frac{1}{8}$ inch square, and therefore intercept all coarse débris.

It is but the work of a few moments to reverse the current and thoroughly cleanse the screens; when the autumn leaves are falling this must be done several times a day, but at other seasons some days elapse between the cleanings. The wire—even galvanized—rusts out in two or three years, and lately the coarser screens have been made of slender rods of oak, which will undoubtedly prove more durable.

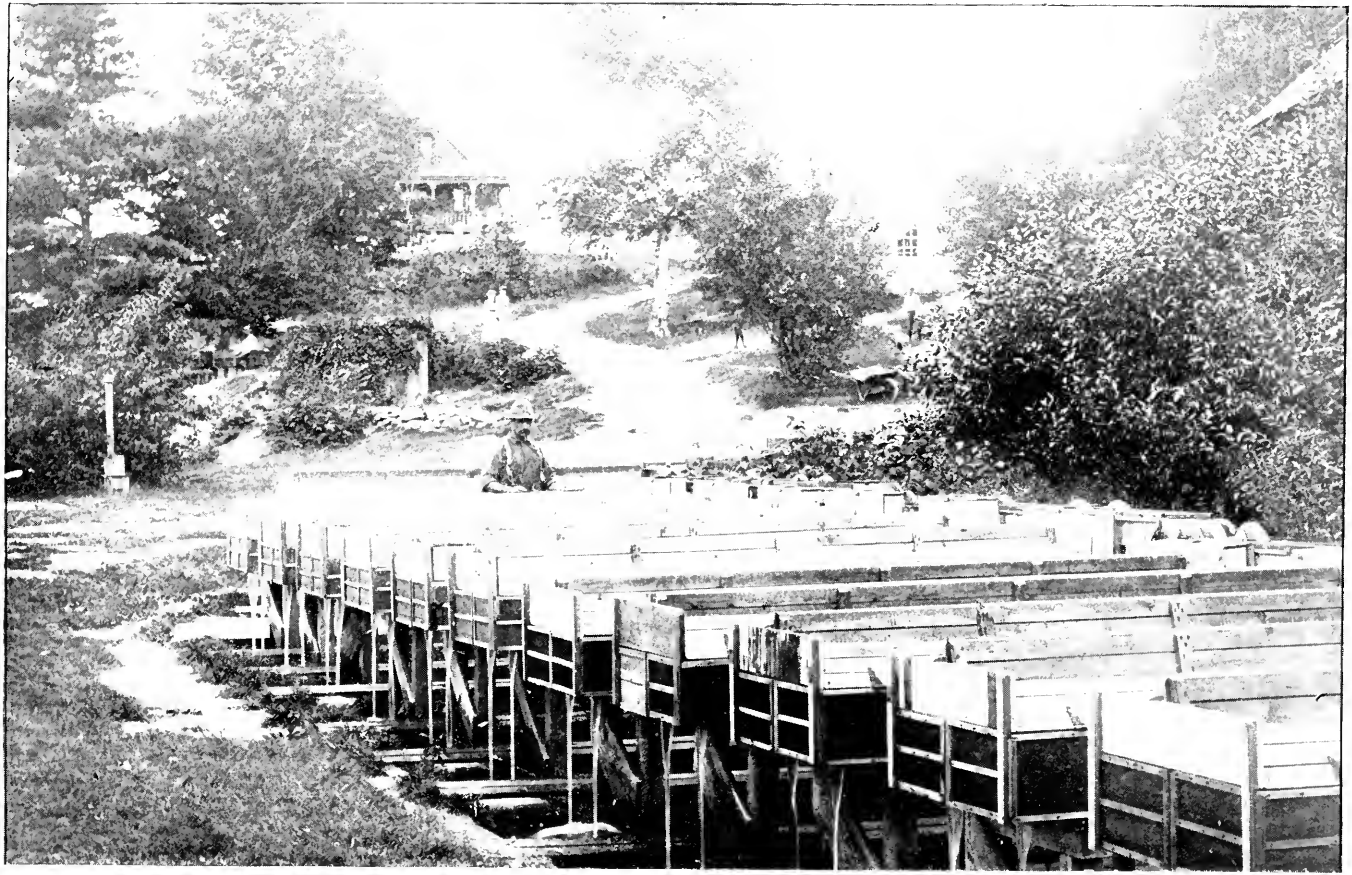
None of the filters described will intercept the finest sediment, and the water is finally passed through a capacious wooden reservoir, 30 feet long, 8 feet wide, and $5\frac{1}{2}$ feet deep, before it reaches the troughs. This answers the purpose well for the amount of water supplied by the filter last described (about 500 gallons per minute) and is regarded as well worth having, though even this will not insure limpidity in the water when the brook is swollen by rains.

It may be mentioned that this reservoir is kept brimful at all times, so that all portions of the woodwork, except the railing surrounding it, are kept continuously wet and thus insured against decay for a very long period of years.

CRAIG BROOK HATCHERY AND ITS EQUIPMENT.

The Craig Brook hatchery derives its water supply from the brook, which has its source in Craig Pond, but which receives in the lower part of its course many copious springs. This spring water has some advantages, but possesses the serious disadvantage of such high temperature in winter as to unduly hasten the development of the eggs, causing them to hatch early and necessitating shipments of eggs in December.

Accordingly, an aqueduct from a point on the brook above the springs brings to the hatchery a supply of cold water for winter use, in which eggs taken the first of November will not hatch until the following April. This is important, as, if the product of the season's hatching is to be liberated as fry, the late date of hatching will bring them to the feeding stage about the time when suitable food abounds in



SALMON REARING-TROUGHS, WITH RESIDENCE AND BARRACKS IN BACKGROUND, CRAIG BROOK STATION, MAINE.

open waters, and if they are to be reared it is well to shorten up the sac-stage and to have the early feeding-stage fall at a date when the temperature of the water is rapidly rising, which will get the fish quickly through that most difficult of all stages of growth.

The aqueduct is about 1,600 feet long, with a bore 4½ inches, and has a nearly uniform descent and total freedom from depressions, and is from end to end one single piece of cement concrete. It delivers to the hatchery about 100 gallons of water per minute, which is sufficient for the development of 4,000,000 eggs, and possibly many more. It was built in place around a slightly tapering core, which was drawn forward as fast as the mortar set, and it has now done good service for seventeen years. By this means the temperature of the hatchery water is maintained 3° below that of the brook modified by the springs. During the five months from November 1, 1895, to April 1, 1896, the mean temperature in the hatchery was 36.65° F.

COLLECTION OF STOCK SALMON.

The only salmon fisheries available for the purpose of supplying Craig Brook station with breeding fish are those carried on by weirs about the mouth of the Penobscot. Arrangements are made early in the season with weir fishermen to save their salmon alive and deliver them daily to the collecting agent of the station, who makes the rounds of the district about low water with a small steamer, which tows the cars containing the fish on the flood-tide to Orland village, where they are passed through the lock about high water and taken by a crew of oarsmen to the inclosure at Dead Brook.

In anticipation of this work, the fisherman places the floor of his weir a little lower than he would otherwise do, so that at low water the salmon may have water to swim in instead of being left high and dry by the retreating tide, in case of an accidental delay or failure to visit the weir at the usual hour. It is, however, the ordinary practice to take the salmon out at each "fish-tide," i. e., low water, and place them in a car. Cars enough are stationed among the fishermen to bring one at least in each neighborhood, and in most cases the car is brought alongside and the salmon transferred to it directly from the weir, though in some cases it is necessary to place the salmon first in a box, in which it is carried by a boat to the car. The car employed is made from the common dory, divided transversely into three compartments. The central one, which is much the larger, is occupied by the fish, and is smoothly lined with thin boards and covered with a net to prevent the fish jumping out or being lost by the car capsizing, which sometimes occurs, while to guard them from fright and the rays of the sun a canvas cover is drawn over all.

The first cars of this form had iron gratings to separate the central from the forward and after compartments, the water being admitted through the forward and discharged through the after compartment, but this was objectionable because the salmon were constantly seeking

to escape through the forward grating, and often injured themselves by rushing against it. Smooth wooden gratings were afterwards used and for many years cars were employed in which the compartments were separated by tight board partitions, the openings for the circulation of water communicating through the sides of the boat directly with the fish compartment and being, of course, grated. This was a very satisfactory form, but when it was found desirable and practicable to use ice in transportation, the forward compartment became the ice-room, and it was necessary to perforate the partition again to admit the cold water to the fish. Finally, stout woolen blanket cloth was substituted in the partitions, with eyelet holes to afford passage to the water. This is the form now in use, in which the water is admitted through openings in the sides to the ice-room, from which it passes through the fish-room to the after room, whence it is discharged.

The car is ballasted so that the rail is just above water or, in case of an unusually large load of fish, a little below it. All the openings communicating with the outside are controlled by slides, which can be closed so as to let the car swim high and light when it is towed empty.

The boxes used for the transfer of salmon hold about 90 gallons each, and are 2 feet wide, 2 feet deep, and 3 feet long, with a sliding cover, in the center of which is an inch auger-hole for ventilation. Such boxes were used at Bucksport from 1872 to 1874 to convey the salmon on drays from the cars to the inclosure, a distance of a little over a mile; six or eight salmon were taken at once, the box being filled brimful of water, which was brackish and generally clear and cool. Though the largest fish could not lie straight in the box, and the time occupied in transit was commonly twenty minutes, they as a rule arrived at the pond in good condition.

To avoid injury to the fish in transferring them to the cars, fine dip nets, lined with woolen flannel of open texture, are used. The bow on which the net is hung is 22 inches in diameter, and to secure a net of ample width three ordinary nets, 36 inches in depth, are cut open down one side quite to the bottom, and then sewed together, giving thus three times the ordinary breadth without increasing the depth.

The collection of salmon is begun each season usually from the 20th of May to the 1st of June, but as the maximum temperature that the fish fresh from the weirs will endure is about 75° F., the temperature of the water through which the cars are towed must be taken into consideration, and the collection not be postponed until too late in the season. If the collection is prolonged, this difficulty is obviated by using ice, as it has been found that by moderating the volume of water passing through the car and introducing it all through the ice compartment it is possible to keep a uniform temperature in the compartment in which the fish are held several degrees below that of the water in the river, thereby insuring the safe transfer of the salmon.

The principal sources of Dead Brook are two small lakes, and on some of the tributaries there are considerable springs. While the

water is slightly purer than that of ordinary brooks, it is by no means so transparent as that of Craig Brook, and the bottom can hardly be be seen at the depth of 4 feet. This circumstance is regarded as favorable. The inclosure is located on the lower stretches of the brook, not more than half a mile from its mouth, with low banks on either hand and a very gentle current flowing over a bed that is for the most part gravelly but in part consists of a peaty mud that supports a luxurious growth of aquatic vegetation. The general depth is less than 4 feet, but two of the pools are 8 feet deep and another is 6 feet deep. The width of the stream is from 20 to 80 feet. The inclosure occupies the entire stream for a distance of 2,200 feet, embracing an area of about 2½ acres. At either end is a substantial barrier, consisting of wooden racks, which obstruct the current very slightly but confine the salmon securely. The lower barrier is provided with a gate, which swings open to admit boats, and at the upper barrier are the spawning-house and watchman's camp and a small storehouse.

The temperature of the water during the summer months generally ranges between 60° and 70° F., but the surface temperature occasionally rises to 76°, 80°, and even 84°. During sultry weather the temperature at the bottom has been observed and in the deeper pools has been found to be notably lower than at the surface. Thus a temperature of 75° at the surface has been found to be accompanied by 68° at the bottom; 78° by 74°; and 81° by 72°. It is probable that to the existence of these deeper pools the survival of the salmon through extremely hot weather may be ascribed.

After their liberation in the inclosure the salmon are at first quite active, swimming about and often leaping into the air. This continues for several weeks, after which they become very quiet, lying in the deepest pools and rarely showing themselves until the approach of the spawning season.

Most of the deaths occur during the first few weeks of their imprisonment, doubtless in consequence of injuries received in capture or during transfer, though high temperature in the inclosure itself about the time of the introduction of the salmon may be one of the causes of mortality. Fish that escape the dangers of June appear to become acclimated and able to endure the high temperatures of July and August without injury.

Notwithstanding salmon enter the rivers in spring or early summer, ascending at once to their upper waters and there, in fresh water, awaiting the spawning season, fresh water is not essential to the activity of their reproductive functions. At the Canadian fish-breeding station of Tadoussac, where salmon are almost the only fish cultivated, it has for many years been the practice to hold their brood fish in an inclosure supplied with salt water, which flows and ebbs through the barrier confining the salmon, and the development of eggs and milt is in no wise unfavorably affected.

THE EGG HARVEST.

The natural deposit of spawn by the Atlantic salmon in the rivers of the United States occurs during the months of October and November. In artificial operations at Dead Brook it has rarely been necessary to begin spawning before October 22, or to close later than November 15.*

Dead Brook is commonly at a very low stage in August and September, but it rarely fails that before October 20 there is a very material increase in volume. Whenever a sudden rise occurs, even in August or September, imprisoned salmon are at once excited to activity, and any aperture in the upper barrier sufficient to admit the body of a salmon is sure to lead to loss. As the breeding season approaches the sensitiveness of the fish to such influences increases, and a rise about October 20 is followed by a general movement of the salmon upstream in search of spawning-grounds. Advantage is taken of this circumstance to entrap them at the upper barrier, where a small pound with a board floor and a barbed entrance, like that of a weir, is constructed a few days in advance. The success of this trap depends on the stage of the water, and it is always the case that a portion of the fish fail to enter it, so that the final resort is to a seine, with which the recalcitrant salmon are swept out of pools where they are wont to lie.

The fish are dipped from the trap or from the seine with soft bag-nets, such as are used in collecting them at the beginning of the season, assorted according to sex and condition, to facilitate manipulation, and placed in floating wooden pens, which are moored to the bank in front of the spawn-house. These pens are about 12 feet long and 4 feet wide, with grated sides and floors, affording sufficient circulation of water, and, although indispensable for the convenient manipulation of the fish, the confinement in such narrow quarters leads to considerable chafing of noses and tails, and if long continued affects the development of the sexual functions of the female unfavorably, retarding the maturity of the eggs and even affecting their quality. The capture of the fish from the brook is therefore delayed to the point of risking the deposit of some of the earliest eggs in the brook rather than the possible injuries in the pens.

The spawn-taking operations begin as soon as any females are ready to yield their eggs. A scarcity of males in breeding condition has never yet occurred at this station at the beginning of the season, and hardly ever at its close. Among the earliest captures there are always a few unripe fish, but invariably by the last day of October all are ripe.

The spawning-house consists of a single, plain room, with two doors. From one of the beams hangs a steelyard and a bag, in which salmon are weighed. At one end is a stove, in which a fire is built in very cold weather. At the other end is a graduated board, upon which the

* In Canadian rivers the dates are but a little earlier. Thus at the Gaspé hatchery, in the Province of Quebec, in 1894, the work of spawning began October 10 and closed November 2.

Ripe female salmon.

Male salmon.

EXAMINING FISH FOR STRIPPING.

STRIPPING FEMALE SALMON.

fish are laid for measurement. At the front is a narrow table, on which the eggs are washed; and at the rear the entire side of the room is occupied by a series of shelves, on which the eggs are placed after fecundation and washing.

The spawn-taker, clad in waterproof clothing and wearing woolen mittens, sits on a stool or box, and on a box in front of him is a clean tin pan holding about 10 quarts, which has been rinsed and emptied but not wiped out. A female salmon is dipped up from one of the floating pens and brought to the operator, who seizes her by the tail with the right hand and holds her up, head downward. If unripe, the fish is returned to the pens; if ripe, the spawn will be loose and soft and will run down toward the head, leaving the region of the vent loose and flabby, and the operator, retaining his hold of the tail with his right hand, places the head of the fish under his left arm with the back uppermost, the head highest, and the vent immediately over the pan. At first the fish generally struggles violently and no spawn will flow; but as soon as she yields the eggs flow in a continuous stream, rattling sometimes with great force against the bottom of the pan. Shortly the flow slackens and must be encouraged and forced by pressing and stroking the abdomen with the left hand. It is better to use the face of the palm or the edge of the hand rather than pinch between the thumb and finger; the latter action, especially when working down near the vent, is apt to rupture some of the minor blood vessels, with the result of internal bleeding, and it is better to leave some of the eggs behind to be taken another day than to run the risk of such ruptures.

If the fish in hand is fully ripe, nine-tenths of the eggs are obtained at the first trial. When the operation has apparently gone far enough for the first day, the fish is laid in the weighing bag, and as soon as the weight is recorded is stretched upon the measuring board, whence she is returned to the water, after a stay of 10 or 15 minutes in the air, which results in no permanent injury. Both the weight and length of the fish and the weight of the eggs are recorded, together with anything remarkable connected with fish or eggs.

Large salmon endure transportation and confinement less successfully than smaller ones, and the record therefore shows large numbers of salmon from 29 to 31 inches in length, weighing, including eggs, from 9 to 12 pounds, and yielding $2\frac{1}{2}$ to 3 pounds of spawn (6,000 to 8,700 eggs), with now and then a fish 35 or 40 inches in length, yielding, in some cases, as many as 16,000 to 20,000 eggs.

As soon as the spawn of a single female is taken, a male is brought to the spawn-taker and the milt expressed upon the eggs. The pan is then swayed and shaken violently until the milt becomes well distributed and in contact with every egg. If the quantity of spawn exceeds 3 pounds it is divided and fecundated in two pans instead of one, as it is difficult to secure a good result if the eggs lie in too great

masses. The eggs are passed over to the washer, who repeats the swaying and the shaking, and, having weighed them, pours in a small quantity of water and goes through the mixing process for a third time. After this the eggs are immediately washed by pouring in an abundance of water and turning it off, and repeating the operation until the water appears quite clear, when the eggs are placed on the shelves in the rear of the apartment, to await the process of swelling. When the egg first comes from the fish it has a soft and velvety feeling to the hand, and the outer shell lies loose and slack against the yolk. The presence of water excites the shell to action; its pores absorb water with such force that any foreign object coming in contact is sucked against it, and in consequence of this suction the eggs stick to the pan and to each other. In the course of 20 or 30 minutes this process is completed, the shell is swollen to its utmost extent and is firm to the touch, the space between the shell and the yolk is now filled with water, and adhesion to outer objects ceases.

The eggs can now be laid upon trays and carried to the hatchery. No serious harm would ensue if the eggs should be disturbed during the process of swelling, but it is better not to spread them upon trays until they have attained full size and ceased to adhere to each other, and they are left on the shelves until the spawning for the day is over, when all are carried to the hatchery together. After the absorption of water the eggs must be handled very gently, as they are now susceptible to injury from sudden shocks, such as might ensue from pouring them from pan to pan, or setting the pan containing them down roughly upon a wooden table, and to guard against such injuries the tables and shelves are covered with old nets or other soft material.

CONDITIONS AFFECTING FECUNDATION OF EGGS.

While the spawn of a salmon is, with very rare exceptions, in normal and healthy condition and capable of fecundation within the limits of the spawning season, occasionally a fish is found whose eggs are in some way defective. Sometimes they are developed unevenly, the ovaries containing eggs in various stages of growth, some mature and some rudimentary; sometimes all the eggs of a fish are abnormally small, and sometimes all have defects which render them incapable of fecundation. But among the thousands that have been manipulated at the station not 1 in 300 has had defects involving as many as 20 per cent of her eggs, and in the spawn deemed of normal quality there can hardly be more than 1 defective egg in 400. Among the males no instance has occurred where there was reason to suspect the milt of being of defective quality if secured from a living fish.

In 1872 experiments were made bearing on the duration of the capacity for fecundation of the eggs with interesting results. From eight lots of eggs taken from dead fish, the rates of impregnation ranged from 92½ per cent down to zero. From a fish that had been dead 2

hours 4,400 eggs were obtained, of which only 58½ per cent were capable of fecundation. In one instance eggs taken from a dead fish and kept until the morrow before milting remained so far in normal condition that 12½ per cent were fecundated. In another case 400 eggs from a fish that had been dead 15 hours failed totally; and the same result was obtained with 2,200 eggs taken from four specimens killed two days before.

The same experiments afford evidence as to the result of keeping eggs for various periods of time after they are taken from the fish, and eggs exposed to the air and guarded against contact with water appear to keep better than in the organs of a dead fish. Thus, 200 eggs were kept in a pan without water for 12 hours after they were taken from the fish, and the application of milt then resulted in the impregnation of 90 per cent; of 200 eggs kept in the same way for 30 hours and then treated with fresh milt, 87½ per cent were impregnated; and of 100 eggs kept 4 days and then treated with fresh milt, 12 were impregnated.

Milt taken from a living male and kept in an open dish for several hours retains its powers fully, but experiments with milt from dead fish have given almost wholly negative results. Numerous experiments show that if eggs are merely covered by water, without effort to secure intermixture or the washing off of the mucus that envelops them when pressed from the organs of the mother fish, their susceptibility to fecundation may not be seriously affected by immersion 5 or 6 minutes; but if the eggs are stirred, so as to facilitate the washing off of the mucus and the access of pure water, immersion for 1 or 2 minutes may prevent impregnation.

When thoroughly diluted with water the milt speedily loses its power, the effect being very marked at the end of 30 seconds; diluted with the mucus that accompanies the egg, it will remain effective for a long period. Where water has been carefully excluded, milt has been used successfully after the lapse of 12 hours with landlocked salmon, and this would probably hold with eggs of all kinds of salmon and trout. This property of the mixed mucus and milt has been utilized in impregnating masses of eggs when there is a scarcity of males, as sometimes occurs toward the close of the spawning season. In straining the mixed mucus and milt from the pan of eggs, the lower strata, which are richer in milt than the upper, should be especially secured and the mixture kept in a convenient receptacle. The upper strata of the mixture should not be used, as the milt settles to the bottom. Fresh milt should always be preferred when obtainable.

The eggs are washed as soon as the milt is thoroughly diffused among them, and this can hardly be done too speedily for the milt to act. A careful record of certain lots of eggs that were washed in special haste for experimental purposes shows that they were as well impregnated as those exposed to the action of the milt for a considerable period. Prolonged exposure to the milt has been found to affect the health and development of the embryo unfavorably.

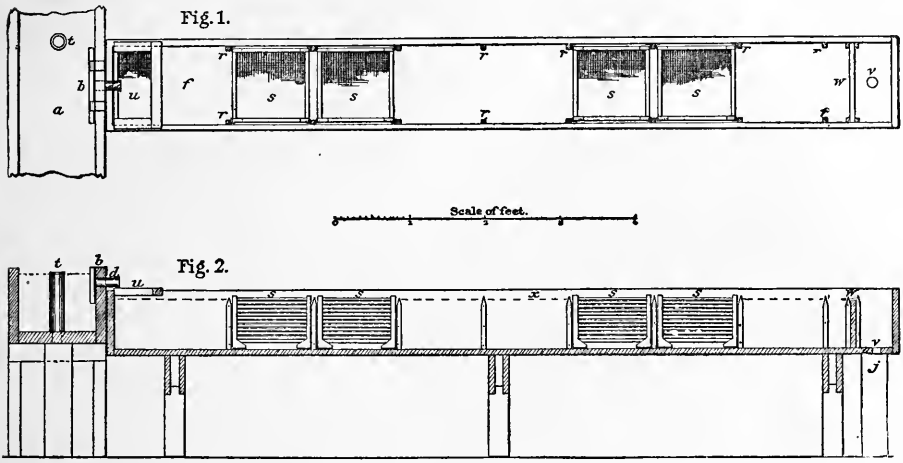
TRANSFER OF EGGS TO THE HATCHERY AND THEIR CARE.

From Dead Brook the eggs are transferred to the hatchery at Craig Brook station, about 2 miles, and spread on trays in the spawning-house. The trays are placed in frames, inclosed in boxes which are padded within to guard against concussion. In spite of all precautions some of the eggs are occasionally killed, though the trays are placed in pans of water and the eggs poured from the spawning-pans with the greatest care. The frames or "stacks" containing the eggs are placed at once in the troughs where they are to be developed.

The trays are $12\frac{1}{4}$ inches square, and constructed by attaching iron wire-cloth to light wooden rims with blocks at the corners, so that when piled up, one above another, there are narrow interstices on all four sides, through which water circulates freely. The rims of the trays are very slender, in order that they may never have buoyancy enough to float, which would necessitate some means of holding them down and increase the trouble attending their manipulation. Southern poplar (whitewood) is commonly used, and a rim $\frac{1}{2}$ inch wide and $\frac{3}{8}$ inch deep answers the purpose well, provided the wire be not very light. The corner pieces are $\frac{1}{8}$ inch thick, and give the interstices just enough width to provide an ample circulation of water, but not enough to allow the escape of salmon eggs, which are nearly $\frac{1}{4}$ inch in diameter. Rusting is prevented by varnishing the wire-cloth with several coats of asphaltum varnish, which works better if made very thin by the use of a large proportion of spirits of turpentine. The same varnish gives a clean and glossy surface to submerged woodwork, and the varnishing is extended to the rims of the trays, the "stack-frames," and interior surfaces of the troughs themselves. Material subject to rust should be used only with great caution. Wire or other metallic forms galvanized with zinc vary in quality. Total loss of eggs has been known to result from the use of galvanized wire-cloth when unvarnished. Careful experiment should precede the use of any particular brand. Tinned wire cloth is better, but whether sufficiently to warrant the extra expense is the question.

In developing eggs, in order to economize room, the trays are piled up 10 or 20 deep in frames that confine them only at the corners and do not hinder the free passage of water horizontally through the "stack." About 2,000 Atlantic salmon eggs are placed on a single tray, and a trough of the ordinary length, $10\frac{1}{2}$ feet, therefore carries 140,000 to 280,000 eggs, with suitable free space at either end. It is therefore an exceedingly compact apparatus and has the further advantage that it can be used in a very plain trough which can, with a few minutes' work, be transformed into a rearing-trough for young fish. For 10-tray stacks the trough is made of pine boards, $12\frac{3}{4}$ inches wide and 9 inches deep inside, and is set up level, with the top about 30 inches from the floor of the room.

The water is fed into one end through a wooden or rubber tube guarded by a wire screen, and is regulated by a simple swinging gate. The outlet is either over a wooden dam or through a hollow plug, either of which determines the height of the water in the trough, which is always maintained just at the top of the covering tray or an eighth of an inch above it.



Trough Arranged for Eggs.

Fig. 1, plan. Fig. 2, longitudinal section.

a, supply-trough	*j*, down-spout.	*u*, screen.
b, screen.	*r*, cleats.	*v*, outlet.
d, supply-pipe.	*s*, stacks of egg-trays.	*w*, wooden dam.
f, egg-trough.	*t*, waste-pipe.	*x*, water surface.

For the regular picking and cleaning, and for other examinations, the stacks are removed from the trough to a table, where the trays can be taken out one by one, set over into an empty frame, and returned to the trough. This can be performed with ordinary caution at any stage of the development of the embryo, without doing the slightest injury, and after the delicate stage is passed the trays and their burden of eggs can be washed at the same time in a pan of water.

WINTER CARE OF EGGS.

The eggs pass the winter in the stacks. They are regularly picked over and the dead ones removed once or twice a week—twice during the first few weeks, on account of the comparatively high temperature then prevailing and the consequent rapid development of decay and growth of fungus. It depends, to a considerable extent, on the water temperature; the water at the beginning of the spawning season varies from 50° to 55° F., and maintains a mean of 43° to 45° F. during the month of November.

The color of a good egg, or of an unimpregnated egg that still retains its vitality, is a translucent salmon pink, with some variations in shade.

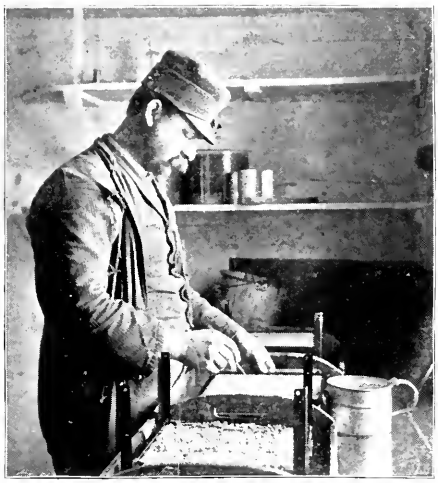
It is possible, by placing it in a favorable light, to get a fairly good interior view, including the detailed anatomy of the embryo. When the egg dies it turns chalky white, becomes wholly opaque, and in a few days, depending on the temperature, decay sets in, and sometimes a white water-mold or fungus begins to grow upon it. The mere decay of the egg would foul the water, thereby injuring the neighboring eggs, and the fungus established on the dead eggs may spread to the living ones. It is therefore essential that the white eggs be removed before they have time to do any injury.

For egg-picking a homemade pair of tweezers, about 6 inches long, is used, made of any convenient wood and tipped with a pair of wire loops of a size to conveniently grasp the egg. The operator lifts the stack of trays carefully from the trough and, to save dripping, carries it on a wooden waiter to a well-lighted table of convenient height, on which stands an oblong pan, 14 by 18 inches, holding about an inch of water.

The stack of eggs to be picked is placed at one end of the pan and at the other end is an empty stack-frame. The trays are examined one by one, dipped in the pan of water, picked (or cleaned by agitation when the eggs are in condition to endure the disturbance), and placed in the empty frame. The air of the room is kept at a low temperature during this process, and the water in the pan is often changed.

The eggs when first impregnated are very sensitive to rude shocks and are handled with great care. Within a few hours the germ begins to develop; in 10 days, at a temperature of about 40° F., the germ-disk appears as a ring of color on the upper side of the yolk. At this date the unimpregnated egg presents the same appearance and does not change much until its death, however long that may be deferred. In the impregnated egg, however, the germ-disk continually enlarges upon the surface of the yolk; the ring of color that marks its edge advances before it, passing quite round the yolk, and closing up on the posterior side.

As early as the thirteenth day the difference between the impregnated and unimpregnated egg is quite plain to the unaided eye after a very little experience, and three or four days later the good egg is marked by a distinct line of color passing around the very middle of the yolk, a phenomenon never appearing in an unimpregnated egg. During this stage, while the embryonic disk is spreading around the yolk, the egg grows constantly more and more delicate, and liable to rupture of its tissues and consequent death on very slight disturbance; but later the tissues grow stronger, and when, about the thirty-fifth or fortieth day, the eyes of the embryo have assumed enough color to appear as two dark dots, the egg has attained hardiness enough to endure rougher handling. Thenceforward, until the near approach of the time for hatching, the work consists simply in picking out the dead ones, occasionally rinsing out the sediment, and sometimes removing the unimpregnated eggs.



PICKING OUT DEAD EGGS

PACKING SALMON EGGS.

HANDLING EGG-TRAYS.

The latter procedure is attended to for the entire stock of eggs, but is of special importance in case of those that are to be transported. It may be performed any time after the good eggs become hardy—that is, after the eyes become black—but becomes easier late in the season. The unimpregnated eggs, which were at first fully equal in hardiness to the impregnated, lose in that respect as time passes, and finally are readily killed and turned white by a shock which does no injury to the impregnated eggs. When this time has arrived, the eggs are turned from the trays into spawning-pans with a moderate quantity of water, and poured from pan to pan back and forth a dozen times, each time falling a foot or more, and striking the bottom of the pan with considerable force, giving each egg a severe shock. They are then returned to the trays and troughs and as soon as convenient are picked, and if the operation has been thorough almost every unimpregnated egg has turned white and is picked out, while the eggs in which the embryos are developing have not suffered at all.

PACKING AND TRANSPORTING.

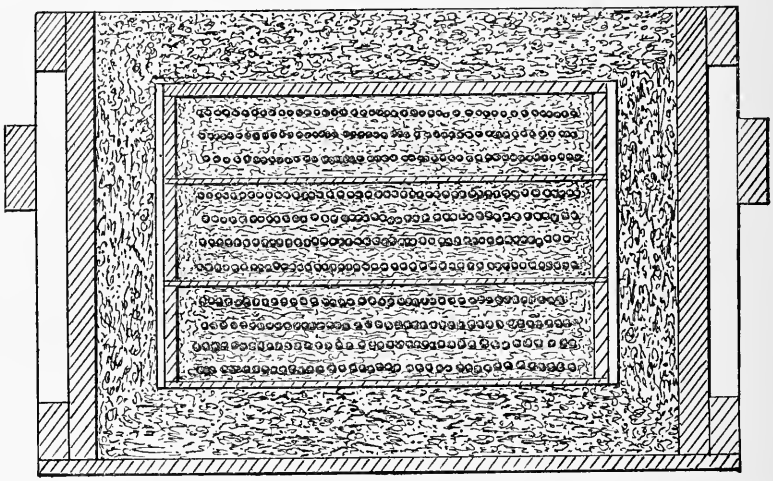
Eggs may be safely transported as soon as the eyes have become thoroughly colored, and until within a few weeks (five or six in cold weather) of the date for hatching. In shipments made too late the shells burst on the way and the embryos perish. The method of packing eggs at Craig Brook is to put them in layers alternating with wet sphagnum moss in shallow wooden boxes, placed in cases of a size to afford on all sides of the inner package a space of $2\frac{1}{2}$ or 3 inches, which is filled with some light, porous material that will form a good nonconductor of heat.

The eggs are thrown from hatching-trays into a large rectangular pan, from which they are poured with water into tin measures which hold 2,500 each. A thin layer of moss is placed in the bottom of a packing-box. A little fine snow is sifted upon the moss, and on this is spread a piece of mosquito netting that has been soaked and rinsed in clean water. A measure of eggs is now poured on and spread out and covered by folding over the edges of the netting, which now completely envelops them. Next a layer of moss is spread, followed by snow, netting, and eggs, as before, and the series is repeated until the box is full. The moss must be sufficiently wet, so that with the melting of the snow it shall have all the moisture it will hold, and no more, as it is very desirable to avoid the wetting of the outer packing. If the moss is too dry, the eggs may dry to the extent of becoming indented, and the same result may come from crowding the moss in too hard on the eggs, though it should be pressed in so tightly that the eggs will not slide out of place if the case is turned for a moment on its side.

The temperature of the packing-room is below 50° F., and packing materials are kept in a place which is cool, yet not much below the freezing-point. Salmon eggs packed as above commonly go a three days' journey without completely melting the snow that was sprinkled

under the eggs, and on several occasions eggs of landlocked salmon have been carried across the Atlantic in prime condition, without repacking or special attention.

The packing-boxes are made of thin pine or fir, 12 inches wide and 15 inches long—$\frac{3}{8}$ inch thick boards being used for the end pieces and $\frac{1}{4}$-inch for the other parts—and hold in a single layer, without crowding, 2,500 eggs. The deepest are $3\frac{1}{2}$ inches deep and take four layers, or 10,000 eggs, in a box. To make up a shipment of 40,000 eggs, four boxes are piled up and secured together by tacking strips of wood against the ends, with a cover on the upper box, and this package placed in the case. For a shipment of 80,000, two of the 40,000 packages are put side by side in a larger case, and the proportions selected for the inner boxes are such that the case required is of convenient form.



Longitudinal section of a case of Atlantic Salmon eggs.

Different mosses can be used for packing, but none are so good as the sphagnous moss that can be found in swamps and bogs in most regions of high latitude or considerable elevation. Fresh moss is preferable for a bed for the eggs, though dead, dry moss may be moistened and used with good results.

The moss is gathered in August or September, dried on the ground, and stored in sacks or in bulk until wanted. It retains its freshness through the following winter, not heating like most organic materials. It is exceedingly light, and the best nonconductor known, with the possible exception of asbestos. It is used dry in the outer packing, mainly to save weight, but when protection against freezing is all that is sought, wet moss is better, as frost penetrates wet moss more slowly than dry. When moss can not be had, there are many substitutes which may be used for the protective envelope, such as dry forest leaves, chaff from a haymow, chopped hay, or even crumpled paper; but the latter should not be allowed to become wet.

HATCHING.

As the time for hatching draws near, the eggs are placed on trays provided with legs or some other support to keep them up from the bottom of the trough. Brass nails driven into the under sides of the tray rims are good temporary legs, and after the hatching is over they are readily removed and the necessity of a special set of trays for hatching is avoided. When there are plenty of troughs, these trays stand singly on the bottom of the trough, but when it is necessary to economize room two or even three are disposed one above another. When no necessity exists for economy of space, 4,000 eggs are allowed a whole trough, which is at the rate of 400 to the square foot; 2,000 or even 5,000 to the square foot may be carried through hatching and the entire sac stage, but the latter number involves risky crowding.

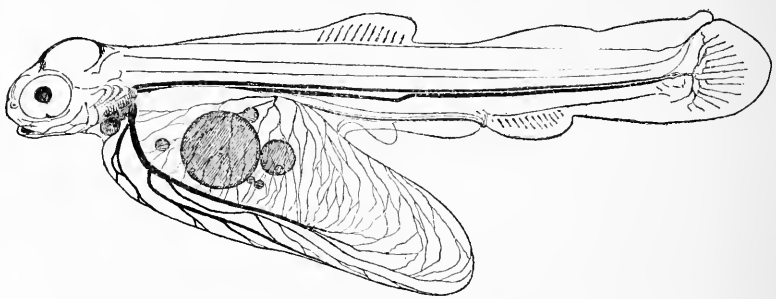
The hatching is sometimes expedited by giving eggs that are just at the hatching point a decided shock, similar to that given at an earlier date to kill the unimpregnated ones; also by the temporary stoppage of the water supply. But at Craig Brook it is the custom to lay the eggs out in good season and allow them unlimited time in which to hatch, sometimes a week, sometimes two weeks. The earliest lots commonly hatch the latter part of March, and it is not often that any remain unhatched after April 20. The mean duration of the egg stage is therefore about 157 days, during which the mean temperature of the water has been about 37° F. While hatching is progressing, the outlet screens are closely watched to keep the empty shells from clogging them up; for when a considerable part of the screen is clogged the force of the current through the open spaces is greatly increased, and the soft and yielding sacs of the fish are liable to be drawn through the meshes.

THE SAC STAGE.

When the shell breaks, though it has been coiled up in a space less than $\frac{1}{4}$ inch in diameter, the trunk of the newly hatched salmon at once straightens out to a length of about $\frac{3}{4}$ inch. The yolk, scarcely diminished from its original size, hangs beneath and constitutes the greater part of the bulk of the fish. The young salmon is for a while more unwieldly than a tadpole. When frightened he sculls about with great energy, but makes slow progress and is fain to lie on his side on the bottom of the trough or crowd with his companions into a corner. The sac is a store of nutriment, which is gradually absorbed into the other parts of the fish; and so long as it lasts the young salmon will not eat. The interval between hatching and total absorption of the sac varies with the temperature, the mean at Craig Brook in April and May being about six weeks.

As time passes the embryo fish grows more and more to resemble the adult, his body acquires strength, and his fins assume form and become more effective as organs of propulsion. At last his digestive system

assumes its functions and rouses the desire for food. Until this time, intent only on hiding, the fry have clung obstinately to the bottom and to the dark corners, but now they scatter about through the water, with heads upstream, watching for prey. This indicates that they must be fed. During this period of his growth it is simply necessary to see that the young fish has plenty of water, that there is no hole or crevice into which he can be drawn by the current, and that he is protected from enemies, such as large fishes, minks, rats, kingfishers, and herons. If not in a house, well-fitting covers must be provided to the troughs and impassable screens command both ends. The screens are of fine wire-cloth, 12 or 14 meshes to the linear inch, and present a surface of 14 square inches to each gallon of water passing through them each minute. Thus, if there are 4 gallons of water passing through the trough each minute the portion of the screen beneath the surface of the water must measure as much as 56 square inches, and if the screen is 12 inches wide the water must be $4\frac{2}{3}$ inches deep on the screen.



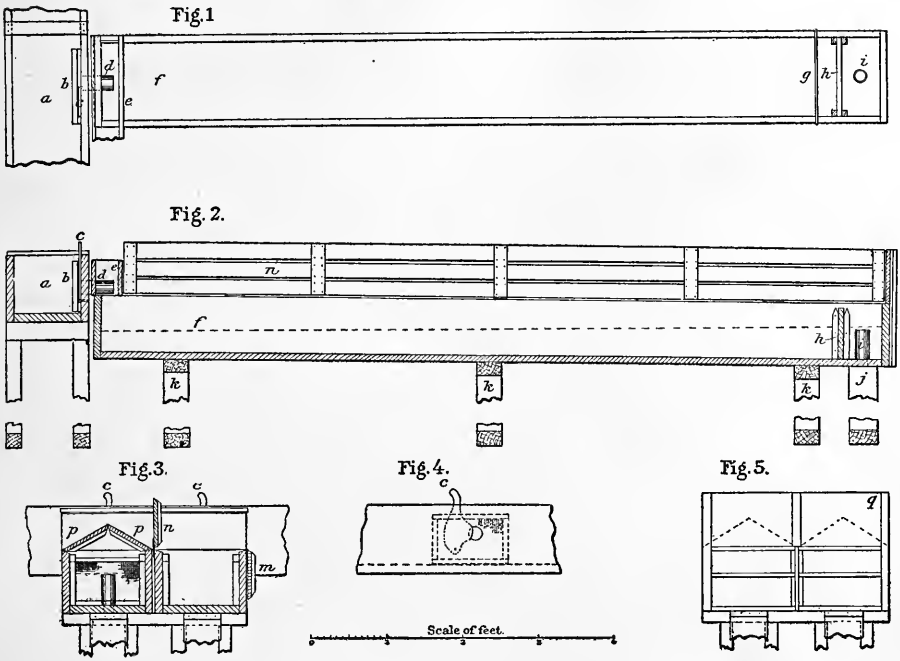
Atlantic Salmon, recently hatched.

REARING.

The leading feature of the work of the station is the rearing of fry to the age of six or eight months. The fishes reared are mainly Atlantic salmon, but landlocked salmon, American brook trout, European brook trout, rainbow trout, steelhead trout, American lake trout, Swiss lake trout, Scotch sea trout, and saibling have also been handled. The fish are fed wholly on artificial food from about June 1 till October or November, when they are mostly liberated. To a limited extent they are kept in artificial ponds, but troughs of the same form and dimensions as those already described for use in developing the eggs and in hatching have given satisfactory results and have been adopted for the most part. Each trough is provided with a changeable outlet screen and below the screen discharges the water through a hole in the bottom, into which is fitted a hollow plug, the height of which determines the depth of water in the trough. The hollow plug plays an important part in the daily cleaning of the trough, which will be referred to further on.

The use of the troughs in the open air, which, in the absence of commodious buildings, is a necessity, compels the constant use of covers to keep out vermin; and wooden covers in pairs, running the whole length

of the trough, hinged to its sides, and, when closed, assuming the form of a roof at an angle of 45°, were finally adopted. These covers are made of thin boards, $\frac{5}{8}$ inch thick, sawed in narrow pieces, which are put together so as to leave in each corner two cracks open $\frac{1}{4}$ inch wide for the admission of light when the covers are closed. When open they may be fixed in an upright position, thus increasing the height of the sides and guarding against the loss of fish by jumping out.



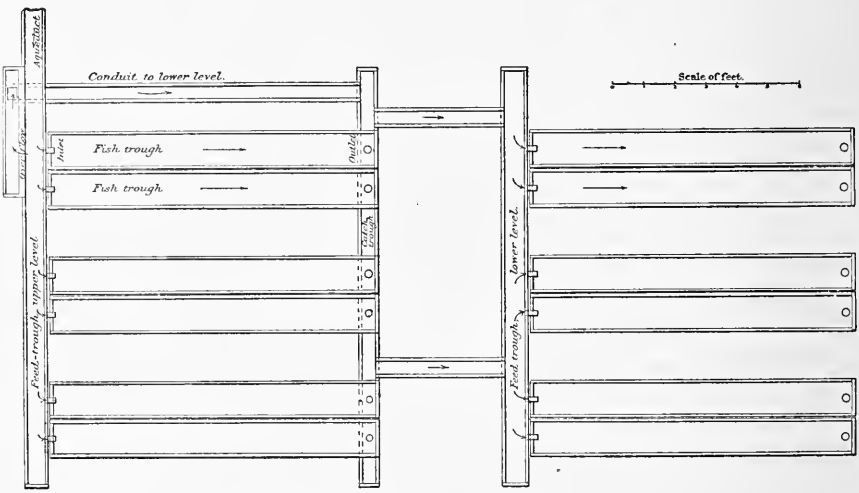
Troughs arranged for Rearing.

Fig. 1, plan. Fig. 2, longitudinal section. Fig. 3, cross-section near foot of trough. Fig. 4, inlet, with rocking gate. Fig. 5, elevation of lower end.

a, supply trough.
b, screen.
c, rocking gate.
d, supply-pipe.
e, water-board (to spread the water and throw it down).
f, fish-trough.
g, gripe, to prevent spreading of sides.
h, outlet screen.
i, hollow outlet plug.
j, down-spout.
k, supports.
l, cover.
m, cover open (hanging).
n, cover open (upright).
p, cover closed.
q, end boards (closing aperture).

Water is furnished through rubber or wooden pipes $\frac{3}{4}$ inch in diameter, and the bore of the hollow plug at the outlet is $1\frac{1}{4}$ inch or larger. The inflow is regulated by an oscillating or rocking gate, which is set to admit the desired volume of water. The trough is set with the upper end an inch or two higher than the other, to facilitate cleaning out, and the water is kept during the summer about 4 inches deep at the lower end.

The troughs are supported by a suitable framework at a convenient height from the ground and arranged in pairs with their heads against a long feed-trough, constructed of pine boards and perforated on the side by the feed-pipes, over each of which is a capacious screen to prevent clogging by leaves or other floating debris. A frame 6 by 12 inches, covered on its outer side by wire-cloth of $\frac{1}{4}$ inch square mesh, answers the purpose of a screen so well that water from an ordinary brook can be admitted to the feed-trough without previous filtering or screening and with little or no danger of a stoppage of water in any of the fish-troughs. Such screens over the feed-pipes might be made the sole dependence, were it not that the labor attending their cleaning would be greater than that required by a separate filter or screen.



Stand of Troughs for Rearing Atlantic Salmon.

The system represented here by 12 troughs in two series may be extended to many hundreds of troughs in four (or more) series, each series on a different level and receiving water from the series next above, the fall from one to another being about 4 feet. In the drawing the series of 6 troughs on the left is supplied with water directly from the upper "feed-trough" (i. e., supply-trough), and they discharge into a catch-trough, from which the water is carried to the supply-trough ("feed-trough") of the lower level. If the aqueduct supplies more water than the upper series of troughs can use, the surplus passes by way of the "overflow" directly to the catch-trough and thence to the supply-trough of the second series. With a fall of 4 feet, the catch-trough and the conduits that lead from it are below the walks which give access to the troughs on both sides and at the lower end.

The number of fish assigned to a single trough is ordinarily 2,000, and the volume of water given them is commonly 5 gallons per minute. Generally the water is used but once in troughs and is discharged

into conduits leading to ponds where larger fish are kept; but a stand of 100 troughs has lately been set up with the design of using all the water twice; and for many years there has been one system of 52 troughs, arranged in four series, which use in succession the same water, the young salmon thriving quite as well in the fourth series as in the first.

On one occasion a few of them were maintained for several weeks in the warmer water of a neighboring brook, where a trough was set up and stocked with 100 young salmon taken from one of the troughs at the station July 30. The temperatures observed between 1 and 4 p. m. in the fish-trough on successive days from July 30 to August 14, not including August 1 or 10, were as follows: 79°, 75°, 77°, 79°, 82°, 82°, 78°, 76°, 76°, 76°, 74°, 74°, 74°, 74°, F.

The fish were fed the same as the lot out of which they were taken, except that they received food only once a day instead of twice, and were returned to the station October 7 without a single loss during the experiment. Moreover, they were all weighed October 10 and found to average 100.6 grains, while those of the original lot that had remained at the station, with a temperature between 50° and 71° F., averaged only 56.1 grains. While the greatly increased weight of the fish kept in the stream was owing in part to more space, as the 100 had as large a trough as 1,505 at the station, the higher temperature was undoubtedly one of the factors that contributed to the gain in weight, and it is at least plainly shown that the warm water was not unhealthful.

Though small ponds, excavated by the former proprietor, were in existence at the station and used to some extent for rearing young fish in their first summer as far back as 1888, and older fish have been kept in small ponds each season since that, it was not until 1896 that enough pond work was done to furnish data of importance.

The ponds for rearing Atlantic salmon are among the series known as the "south ponds," occupying a smooth piece of ground sloping toward Alamoosook Lake at a grade of 1 in 8. Formerly it was mostly a swale, watered by a copious spring at its head. This series comprises 19 ponds of rectangular form, about 50 to 90 feet long and 15 feet wide, with a depth of 2 or 3 feet. The water supply of those used for Atlantic salmon is derived from Craig Brook by an aqueduct tapping it at a point where two parts of Craig Pond water are mingled with one part spring water, being substantially the same as the water supplying the most of the rearing-troughs. From 5,000 to 10,000 fish that have been fed in troughs during the early part of the feeding season are placed in each pond, and for the remainder of the season are fed the same food that is given to the fish left in the troughs; and the results indicate that the stock of fish might be safely increased.

While the greater part of the salmon reared at Craig Brook are liberated in October, when about seven months old, in 1891–92 about 16,000 were carried through the winter, most of them in tanks sunk in the ground, and nearly as many have been wintered some other

seasons. Fish may also be kept all winter in troughs in the open air by occasionally spreading blankets over them in exceptionally cold weather, and keeping the conduits carefully covered.

The fish surviving the summer season are generally counted and weighed in October, in the following manner: A large number of them are dipped up from a trough in a small dip net made of cheese-cloth, and from this, while it is hanging in the water in such a manner that the fish can not escape, they are dipped out a few at a time, in a small dipper or cup, counted, and placed in another bag net until a sufficient number (generally 200) are counted, when they are lifted out of the water, held a moment in the air to drain, and all turned quickly into a pail of water which has previously been weighed. With care no appreciable amount of water goes with the fish, and the increase in the reading indicates their weight with a fair approach to accuracy, and with care and celerity of action it is quite safe for the fish.

The size attained by the fish varies greatly, being affected by the water, the space allowed, the feed, and perhaps by hereditary influences; but when seven months old a trough-reared salmon is generally from 2½ to 3 inches long and weighs from 35 to 100 grains, the maximum being about 130 grains and the minimum as low as 7 grains, the general mean for 1896 being 45.8 grains. Salmon reared in ponds have been far more thrifty, their general average in 1896 being 101 grains.* The losses in ponds from July to October were rather heavy, being 11.7 per cent, owing to depredations of frogs, birds, and cannibal fish. The losses in the troughs during the entire season were 9.1 per cent, but most of these were in the early stages of fryhood. After July losses in troughs are always very light.

MATERIALS FOR FISH FOOD.

At Craig Brook station there have been used butchers' offal, flesh of horses and other domestic animals, fresh fish, and maggots. Experiments have also been made with pickled fish, blood, fresh-water mussels, mosquito larvæ, miscellaneous aquatic animals of minute size,

*A very interesting comparison between the results of rearing in troughs and ponds is afforded by the record of two lots of steelhead trout during the season of 1896. All the fry of this species that were devoted to rearing were fed in troughs until July 22, when some of them were transferred to a pond which has an area of about 1,100 square feet and another lot was kept in a trough. The two lots were fed exactly alike, about one-sixth of their nutriment being live maggots, and five-sixths chopped meat, liver, and other butchers' offal. November 7, the lot in the trough was overhauled, and the 762 survivors found to weigh 10 pounds 4 ounces, or an average of 94 grains. Three days later the pond fish were seined out and the 7,398 survivors found to weigh 235 pounds 10 ounces, an average of 223 grains. It is not believed that natural food occurring in the pond contributed much to this result, and it would appear that the controlling factor in the case was the space afforded the fish. Leaving out of the account the difference in depth, in the pond there were less than 7 fish to each square foot of area, while in the trough, which had an area of about 11 square feet, there were to each square foot 69 fish. A similar illustration was furnished by 41 rainbow trout of the hatching of 1896 that got astray in one of the ponds and were taken out November 11, weighing 480 grains each. Those of the same age, reared in troughs, attained during the season only a weight of 136½ grains each.

flour, and middlings. The butchers' offal comprises livers, hearts, and lights, which are collected from the slaughter-houses twice or thrice weekly, and preserved in refrigerators until used.

The flesh of old and worn-out horses has been used each year since 1892 in the same way as the butcher's offal, with very satisfactory results; the parts that could be chopped readily have been fed direct to the fish so far as needed, and other parts have been used in the rearing of maggots.

Next to chopped meat maggots have constituted the most important article of food, and their systematic production has received much attention. A rough wooden building has been erected for this branch of the work, and one man is constantly employed about it during the summer and early autumn months. The maggots thus far used are exclusively flesh-eaters, mainly those of two undetermined species of flies; the first and most important being a small, smooth, shining green or bluish-green fly, occurring in early summer and remaining in somewhat diminished numbers until October; and the other a large, rough, steel-blue fly that comes later and in autumn becomes the predominating species, having such hardiness as to continue the reproduction of its kind long after the occurrence of frosts sufficiently severe to freeze the ground.

To obtain maggots meat is exposed in a sheltered location accessible to flies during the day. When well stocked with the spawn of the flies it is placed in boxes, which are set away in the "fly-house" to develop; when fully grown, the maggots are taken out and fed at once to the fish. Stale meat, parts of the butchers' offal and of the horse carcasses not adapted to chopping; fish, fresh, dried, or pickled; fish pomace from herring-oil works, and any animal refuse that comes to hand, are used to entice the flies and afford nourishment for the maggots. Fresh fish, when not too watery or oily, like alewives and herring, is very attractive to the flies, and in proper condition may serve as well as fresh meat. Fish dried without salt or smoke and moistened before using is, when free from oil, a superior article. Its preparation presents some difficulties, but in winter it is easily effected by impaling whole fishes on sticks and hanging them up under a roof where they will be protected from rain without hindering the circulation of the air; in this way many flounders and other refuse fish from the smelt fisheries have been dried.

It is usually necessary to expose meat but a single day to obtain sufficient fly spawn; the larvæ are hatched and active the next day, except in cool weather, and they attain their full growth in two or three days. To separate them from the remnants of food the meat bearing the fly spawn is placed on a layer of loose hay or straw in a box which has a wire-cloth bottom, and which stands inside a slightly larger box with a tight wooden bottom. When full grown, the maggots work their way down through the hay into the lower box, where they are found nearly free from dirt.

When young salmon or trout first begin to feed they are quite unable to swallow full-grown maggots, and small ones are obtained for them by putting a large quantity of fly spawn with a small quantity of meat, the result being that the maggots soon begin to crowd each other and the surplus is worked off into the lower box before attaining great size. No attempt is, however, made to induce the young fish to swallow even the smallest maggots until they have been fed a while on chopped liver.

Maggots are produced and used in considerable numbers, sometimes as many as a bushel in a day. The fish eat them eagerly, and appear to thrive on them better than on dead meat. Having great tenacity of life, if not snapped up immediately by the fish they remain alive for a day or two, and, as they wriggle about on the bottom, are almost certain to be finally eaten, which is a great gain in cleanliness and economy, as the particles of dead flesh falling to the bottom are largely neglected by the fish and begin to putrefy in a few hours and foul the troughs. As the growth of maggots can be controlled by regulation of the temperature, they may be kept all winter in a pit or cellar and used as food for fish confined in deep tanks not easily cleaned.

In the rearing of maggots the offensive odors of decaying flesh may be partly overcome by putting it away in boxes, after the visits of the flies, and covering it with pulverized earth. Only flesh-eating maggots have yet been tried, and the trouble may possibly be rectified by cultivating the larvæ of other species, such as the house-fly, the stable fly, etc., or a little white maggot known to grow in heaps of seaweed, if their rate of growth is found to be satisfactory.

Occasional use has been made of fresh fish for direct feeding, but when thrown into the water after chopping it breaks up into fibers to such an extent that it is not satisfactory, unless in a coarsely chopped form, for the food of large fish. A few barrels of salted alewives have been used, and, if well soaked out and chopped, they are readily eaten by the larger fish and can be fed to fry, but are less satisfactory with the latter, and, like fresh fish, break up to such an extent that they are only to be regarded as one of the last resorts.

Fresh-water mussels, belonging almost wholly to a species of *Unio*, have been occasionally gathered with nets or dredges in the lake close to the station and opened with knives and chopped. The meat is readily eaten by all fishes and appears to form an excellent diet. It is more buoyant than any other article tried, sinks more slowly in water, and gives the fish more time to seize it before it reaches the bottom; but the labor involved in dredging and shelling is a serious drawback.

During the seasons of 1886 and 1888 some use was made of mosquito larvæ, collected from pools of swamp water by means of a set of strainers specially devised for the purpose and from barrels filled with water disposed in convenient places near the rearing-troughs. The larvæ (or pupæ) were strained out and fed to the fish. No kind of food has been

more eagerly devoured, and apparently no other food has contributed more to the growth of the fish; but the time expended in collecting is out of all proportion to the quantity of food secured. Perhaps a series of breeding-tanks arranged in proximity to the fish-troughs, into which the water containing the larvæ might be drawn when desirable by the simple opening of a faucet, would reduce the labor involved.

Middlings and flour have been tried in combination with blood from the shambles, but did not appear to satisfy the fish so well as the various forms of meat, and their use has, therefore, not been continued. They were fed in the form of a pudding composed of two parts blood and one part flour or middlings, cooked carefully to avoid burning, and the mixture was then passed through a meat-chopper and ladled out with a spoon, like other chopped food.

The growth of live food in the ponds themselves in which the fish are maintained has been the subject of study. Ponds several years old and well stocked with vegetation were at one time devoted to these experiments. They had been empty during the preceding winter, and in the spring were fertilized with various sorts of animal and vegetable refuse. They were stocked with different species of crustacea native to the region, including shrimps (*Gammarus*) and entomostraca, of the genera *Daphnia*, *Ceriodaphnia*, *Sida*, *Cyclops*, *Polyphemus*, etc., which were systematically collected from open waters by nets and other apparatus and placed in the ponds. These forms all multiplied there, some of them enormously, but no means was found of inducing continuous or frequent reproduction of them, and the young fish soon exhausted the supply.

In serving the food the attendant carries it with the left hand—in a 2-quart dipper if chopped meat, in a larger vessel if maggots—and, dipping it out with a large spoon, strews it the whole length of the trough, being careful to put the greater portion at the head, where the fish nearly always congregate. Finely chopped food, for very young fish, is slightly thinned with water before feeding.

It is usual to feed the meat raw except the lights, which chop better if boiled first; but occasional lots of meat, on the point of becoming tainted, are boiled to save them. All meats fed directly to the fish are first passed through a chopping-machine. To fish just beginning to eat, food is given four times a day, or in some cases even six times, but as the season progresses the number of rations is gradually reduced to two daily. In winter such fish as are carried through are fed but once a day.

CLEANING THE TROUGHS.

The troughs are all cleaned daily. When the hollow plug is drawn the water rushes out rapidly and carries most of the debris against the screen. The fishes are excited, and, scurrying about, loosen nearly all the dirt from the bottom; what will not otherwise yield is started with a brush, but after the first few weeks the brush has rarely to be used

except to rub the debris through the outlet screen. Owing to the inclination of the trough, the water recedes from the upper end until the fishes lying there are almost wholly out of water, but, although they are left in that position sometimes for 10 or 15 minutes, no harm has ever been known to result.

TRANSPORTATION AND LIBERATION OF YOUNG SALMON.

The salmon produced at the station have, with few exceptions, been liberated in the Penobscot River or its tributaries, and more than 90 per cent of them in small tributaries within 10 miles of the station. They have been spread about in streams and lakes, at all accessible points. They are transferred in tin cans, holding about 8 gallons, with an extreme height, including neck, of 17 or 18 inches, and a body 15½ inches in diameter and 10 inches deep, making a very broad and low can, well adapted to the use to which it is put. Its great width favors aeration at the surface, and a good deal of dashing about of the water when on the road. The cans are filled to within about an inch from the shoulder, giving opportunity for the water to swash about and aerate itself. Into such a can are put from 200 to 400 Atlantic salmon seven months old, more or less, according to the size of the fish, the temperature of the air, and the weather. The ordinary load is about 300 when the temperature of the water is 52° to 54° F., making 37 fish per gallon. Such loads are entirely safe for the conditions attending the work. The motion of the wagon in which they are carried keeps up the aeration of the water, so that the fish can not exhaust the air. Should the cans stand still a very long time aeration is effected by a force-pump which draws the water from the can and returns it through a tube so that it strikes upon a deflector by which it is broken and scattered in spray. The suction hose is covered with a roomy wire strainer, so that the fish are not drawn in.

DISEASES.

Salmon in all their stages of growth are subject to a variety of diseases. White spots sometimes occur on the eggs attached to the shell, but have no hold on the embryos, so that when the shell is torn off the white spot is seen as a cluster of globular white masses on its inner surface. These appear to be vegetable parasites, perhaps fungoid in their relations, and are never seriously abundant. Other white spots are connected with the yolk-sac itself. These are more serious, but while they result in the death of many embryos, they are by no means always fatal. In 1896 there were hatched at the station some rainbow trout that were badly spotted on the sac. A portion of the fry were divided into three lots for experiment: (*a*) Without spots; (*b*) moderately spotted; (*c*) badly spotted. They were kept separate through the season, and a fair percentage survived, as follows: Of lot *a*, 55 per cent; of lot *b*, 59 per cent; of lot *c*, 43 per cent. In the fall they were

all weighed, and it was found that lot *c* had made a slightly better growth than lot *a*.

One of the most uncontrollable diseases attacks salmon fry midway in the sac stage, and finishes its work before the complete absorption of the sac. The most evident symptom is the appearance of scattered white spots in the sac; the fish cease to try to hide, but lie scattered about on the bottom of the trough; the spots increase in size, coalesce, and finally occupy large areas, especially in the tip of the sac, which becomes quite white. Soon after this the fish dies. The attack on a lot makes rapid progress; for instance, a lot of 2,000 in which, up to April 22, the losses had been from 1 to 9 daily, showed 17 dead on the 23d, and five days later 360 died in a single day. In 1890 this epidemic attacked especially the fry of Atlantic salmon, destroying about a third of them; it also destroyed many landlocked salmon, and some other species suffered heavily about the same time. In 1891 there was not a trace of it. In 1892 it returned again, and out of 305,353 fry of Atlantic salmon it left but 3,874, and these were by no means healthy; but it attacked only Atlantic salmon. Salt and mud were tried as remedies, but though the progress of the disease appeared in some instances checked thereby, no permanent benefit resulted from their use.

In 1890 this epidemic appeared to run in families. There was evidence tending to show that all the eggs coming from a particular mother would have a common degree of liability to the disease—some families being exterminated by it, some only decimated, and others able to resist it altogether. It did not appear to be infectious, as several lots of fry, separated by screens, would occupy a single trough, and in some cases those at the head of the trough would be totally destroyed, or nearly so, and those below them escape from attack.

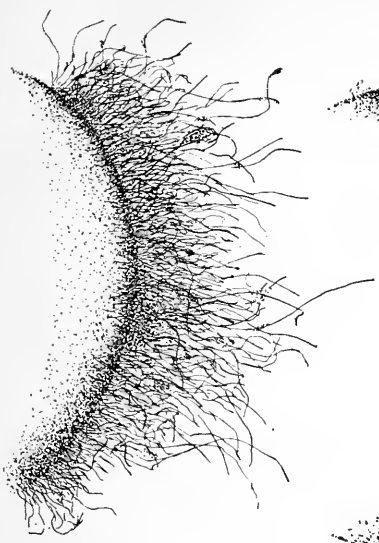
The only other diseases of Atlantic salmon that demand notice here are connected with the so-called fungus, belonging to the group of water molds called *Saprolegniæ*, and probably to the genus *Saprolegnia*, one species of which, *S. ferax*, is noted as the cause of very destructive epidemics among the adult salmon of Scotch and English rivers. The species that attacks fish eggs is well known to every fish-culturist as a fine white growth of a cottony or woolly appearance that forms upon dead eggs, and when neglected spreads out so as to envelop in its threads a great many of the living eggs surrounding it. It is by no means certain that all such growths belong to one species or even to one genus, but they are much alike in structure and growth and live upon animal and vegetable matter, either as parasites attacking living matter or as saprophytes attacking only dead and decaying matter. There has never been serious trouble with this fungus at Craig Brook station, and great loss from it can only occur in consequence of neglect of the duty of picking out the dead eggs. An instance of its attacking a living egg except by reaching out from a dead one is unknown. Fish

several months old are sometimes afflicted with a similar growth, which may possibly be not the original cause of the disease, but only an attendant symptom. Such an attack was experienced at Craig Brook in July, 1888. The fry of Atlantic salmon were the sufferers and the mortality was considerable, but it yielded promptly to a salt bath.

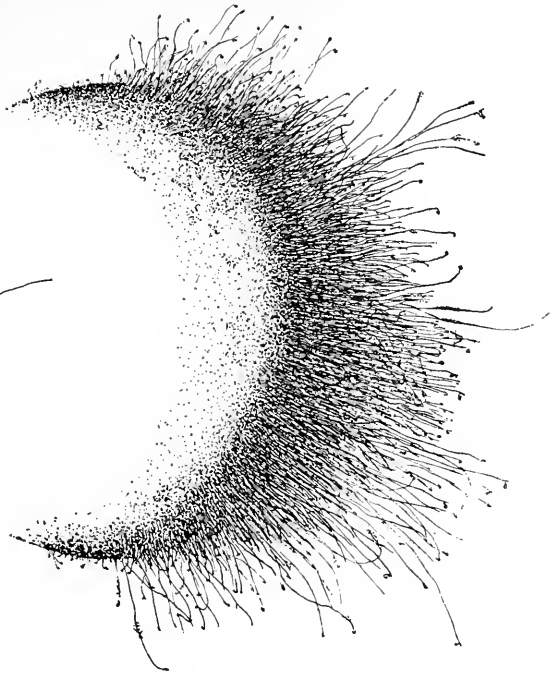
The occurrence of fungus on wounds, even on such as result from the abrasion of the skin or the loss of a scale, is very common, but such cases are rarely fatal, though no remedy be applied. The only serious attack of fungus on adult salmon occurred during the experimental work at Craig Brook in 1871. The first inclosure made to receive the breeding fish was a small and shallow one, made by damming the brook itself at a point where its volume consisted of about 30 per cent of spring water. The fish had suffered considerably from the handling necessary in bringing them so far and from the rough character of the experimental cars in which they were transported. The first of them were placed in the inclosure June 8. On the 12th 2 of them died, on the 13th 2 more, and by the 17th 14 were dead out of 41 received; by the 20th the mortality had increased to such a point that it became evident that not a single salmon would survive unless some change was made in the mode of confining them, and they were all removed and placed in other quarters. Nine of them, already so badly diseased as to be considered hopeless cases, were turned loose in Craig Pond, and part of these recovered and spawned in the autumn following on a gravelly shore, where some of them were taken and found to bear the well-healed scars of their ugly sores.

The symptoms noted were sluggishness and heedlessness; an inclination to swim near the surface of the water; a white, filmy appearance of the eyes, which seemed to be accompanied or followed in many cases by blindness; a white fungoid growth on the abraded tips of the fins and wherever the scales had been rubbed off; white blotches breaking out on all parts of the body, even where there had been no mark of injury, particularly on the head, proving on examination to be patches of white fungus, which, on the parts of the body covered by scales, grew underneath the latter and pushed them from their places.

Experiments in confining salmon in other waters the same season turned out successfully, and it seems that the most important conditions in the case were these: The area of the fatal inclosure was about a quarter of an acre; the water was partly from springs and was so exceedingly transparent that a pin dropped into it could be readily seen at a depth of 6 feet, so that there was practically no protection from the rays of the June sun; the fish had been transported in a common dory with holes bored in the bottom to admit water, a very inferior sort of car compared with those now in use; they had been transported a long distance and passed three separate locks and had finally been hauled in a tub on a cart over rough ground from Alamoosook Lake to the inclosure.



FUNGUS ON SALMON EGG.
(Enlarged 9 times.)



FUNGUS ON SALMON EGG, BEARING REPRODUCTIVE ORGANS.
(Enlarged 9 times.)

REPRODUCTIVE ORGANS OF EGG FUNGUS.
(Enlarged 150 times.)

The conditions at Craig Pond, where some of the worst cases recovered, were these: An area of 231 acres; a maximum depth of 69 feet; exceedingly pure and transparent water, like that of the inclosure.

At two of the other inclosures tried that summer, where there was no attack of fungus, the water was brown and dark, like that of ordinary brooks and ponds, and in the remaining one it was intermediate in character.

These facts point strongly to the character of the water as the cause of the fatality of the disease, and especially to its pellucid character, which exposed the salmon to an extraordinary glare of light, whereby the growth of the pest was greatly encouraged. The recovery in the transparent water of Craig Pond was rendered possible by the great depth of the water, through which but a small fraction of the light of day could penetrate. No doubt the salmon liberated there at once took refuge in the deeper parts. The suggestion naturally arises that artificial shade might be useful in the treatment of such diseases, whether the attacking fungus be identical with that observed in the above instances or a related one.

It is certain, from the promptness with which dead animal matter becomes the prey of saprophytic growths, that the spores of these water-molds are well disseminated throughout fresh waters, everywhere ready to seize upon an opportunity for germination and growth, and that as a general rule these spores are quite unable to seize upon any animal substance which is not already dead or in a diseased condition.

A growth of *Saprolegnia ferax* once established on the body of a salmon is able to extend itself upon and into the living tissues around it, which it seizes upon and destroys. Growing upon a dead egg, it not only ensnares the neighboring living eggs, but sometimes pierces their shells and establishes itself on the internal parts. In one instance the fungus had gone so far as to attach itself to a living embryo, which, on removal from the shell, was found to support on the sac quite a tuft of growing fungus, though neither on the sac nor any other part of the fish was a trace of dead substance discernible.

It has been ascertained that the *Saprolegnia* which attacked the living salmon can be communicated by contact to dead flies, and that *Saprolegnia* found growing in the ordinary way on dead flies in water can be communicated in its turn to living and healthy dace and may so flourish on them as to cause their death.

The impression has prevailed that the *Saprolegnia* which infests the eggs in hatching-troughs originates in or is encouraged by bare wood exposed to water, and that special effort is necessary to prevent its forming; but experience at this station does not show that attacks of fungus on either eggs or fish could be traced to bare wood, and, on the other hand, eggs and fish in troughs carefully varnished with asphaltum are no freer from fungoid or other disease than those in neighboring troughs from which long use had worn almost the last vestige of varnish.

The best precaution against this growth is the careful picking out of dead eggs before there is time for the fungus to grow on them, and in case of a serious attack on fry or older fish to treat them with an exterior application of salt, which, while not a cure-all, is very efficacious in cases of fungous diseases, and, if prudently used, a safe remedy for fish that have reached the feeding stage.

To apply this remedy to fry in the troughs a saturated solution of salt in water is made—that is, the strongest brine that can be made without heating the water. The flow of water in the trough to be treated is then stopped, which leaves it from 3 to 4 inches deep, when enough brine is poured in to make the water in the trough about as salt as common sea-water, about 1.028 specific gravity. The fish are left in this 20 or 30 minutes, unless they exhibit uneasiness, and then fresh water is turned on. Precaution is taken to dilute the brine with an equal quantity of water, to distribute it the whole length of the trough, actively stirring the water to secure an even mixture; and before turning on the usual water supply a large quantity of fresh water is likewise poured in, distributing it the whole length of the trough and stirring as before, to guard against a too sudden change.

Such precautions are especially necessary in the application of salt to very young fish. A large number of salmon in the sac stage was once destroyed by pouring in a little brine without stirring it; it appeared to sink to the bottom and spread out in a layer by itself among the fry, and all exposed to it died.

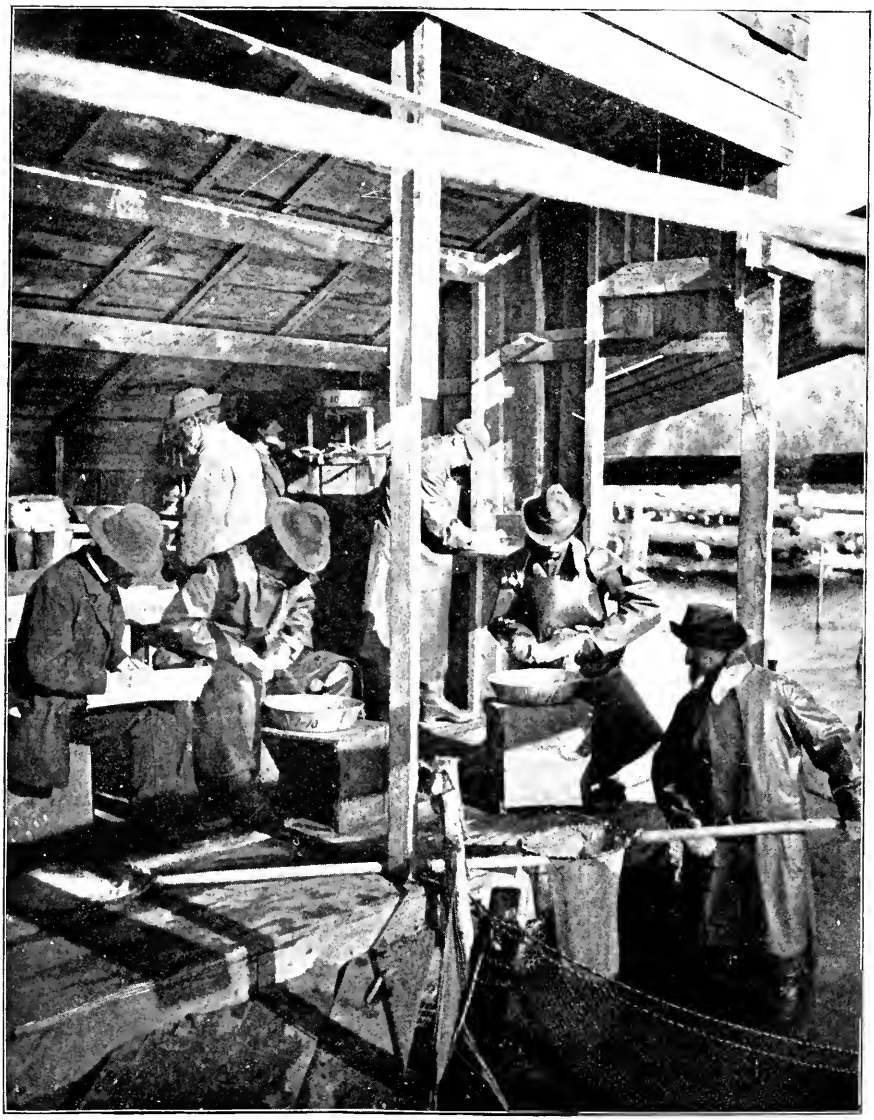
ENEMIES OF YOUNG SALMON.

The young salmon are subject to the attacks of many animals and birds, such as the mink, mole, star-nosed mole, common rat, muskrat, kingfisher, great horned owl, great blue heron, sandpiper, and fish-hawk, besides frogs and all large fishes.

At Craig Brook the mink has caused serious loss. As a protection some of the ponds are covered with galvanized poultry netting, and traps are kept constantly set in the avenues by which this animal is apt to approach. The mole burrows through embankments and thus sometimes causes trouble. The star-nosed mole is known to steal dead eggs, and is suspected of taking live ones. The rat sometimes takes young fish from the troughs. The muskrat burrows in embankments and sometimes eats fish.

The different fish-eating birds occasionally steal fish from the ponds or troughs, but if a careful watch is kept the danger is not great. Frogs may be exceedingly destructive to young salmon, and must be caught out of the fish-ponds.

To avoid loss from cannibalism among the fishes it is necessary to feed them well and to take great care that no large fish get in among the small ones.



TAKING SPAWN OF LANDLOCKED SALMON AT GRAND LAKE STREAM, MAINE.

THE LANDLOCKED SALMON.

The landlocked salmon was formerly regarded as specifically distinct from the seagoing form, but it is now generally considered only a variety. The fish found in Sebago Lake and other localities in the United States is known as *Salmo salar sebago*, and the Canadian form as *Salmo salar ouananiche*. From the fish-culturist's point of view, however, the marked difference between the landlocked and the seagoing salmon in habits and growth must separate them as widely as any two species of the same family.

Landlocked salmon are known to exist only in some of the lakes in Sweden, besides the lakes of eastern North America. They are native to most of the lakes of eastern Labrador, including the waters tributary to Ungava Bay, and find their western limit in Lake St. John and vicinity, on the Saguenay River. Those of the latter district have been much written about under the name of "*ouananiche*."

Doubtless the absence of the seagoing instinct is at the bottom of most of the variations from the normal type of *Salmo salar* which the landlocked salmon exhibits. Its lower tone of color, less permanent sexual marks, and greater liability to ovarian disease, as well as different habits of feeding, may perhaps be referable to the same general cause. There are some other peculiarities, however, which are not so easily explained. For instance, the eggs of the landlocked salmon are considerably larger than those of the sea salmon, and the very young fry are correspondingly larger.

The growth of the young of the Sebago landlocked salmon seems to be more rapid than that of the anadromous salmon, for some specimens more than a foot long still bear on their sides dark, transverse bands, characteristic of young salmon; but it may be that the landlocked fish simply retain the marks of the immature stages to a later period of life. This view is supported by the fact that the dark bands are never completely obliterated from the sides of the landlocked salmon, being always very distinct, even in adult specimens, on the under side of the skin, a character absent among migratory salmon.

The landlocked salmon is smaller than the anadromous salmon, but its flesh is fat and rich and of a very delicate flavor. In game qualities it is, for its size, quite the peer of the larger salmon, and affords keen sport to the fly fisherman. It is, therefore, much sought after, and ranks in public favor among the foremost fresh-water species.

The natural range of the landlocked salmon in the United States is much restricted. Leaving out of the question the salmon formerly frequenting the rivers tributary to Lakes Ontario and Champlain, the extent of whose migration is a matter of doubt, we find them only in four limited districts, all in the State of Maine, namely, the Presumpscot River (including Sebago Lake) in Cumberland and Oxford counties, the Sebec River (a tributary of the Penobscot) in Piscataquis County, the Union River in Hancock County, and the St. Croix River in Washington County. There are some minor differences between the fish of these several districts, of which, perhaps, that of size is most notable. The Sebago and Union River fish are much larger on the average than those of the Sebec and St. Croix. The Sebago salmon average at the spawning season 4 or 5 pounds weight for the males and a pound less for the females, while specimens of 12 and 14 pounds weight are not rare, and there is a record of one of 25 pounds. The Union River fish are about the same size. The St. Croix fish vary in the matter of weight in different parts of their range, but the average weight of either sex at Grand Lake Stream is a little less than 3 pounds; specimens of over 6 pounds are rare, and none is on record of over 10 pounds.

After attempts to collect eggs of landlocked salmon in each of the four regions mentioned, it was found that Grand Lake Stream in the St. Croix district afforded excellent facilities for this work. A hatching-station at that place was operated from 1875 to 1892, and has been recently reopened.

The following notes on fish-cultural methods have special application to Grand Lake Stream:

The landlocked salmon of the St. Croix, though originally well distributed through the lakes tributary to that river and still inhabiting a great many of them, finds in some a much more congenial home than in others, its favorite abode being Grand Lake on the Schoodic River. This body of water is of irregular shape, about 12 miles in length and 4 in extreme breadth, fed almost wholly by short streams that form the outlets of other lakes, and from this cause, as well as from the fact that it drains a gravelly country and is girt with clean rocky shores, it is one of the purest of the Maine lakes. Its greatest depth is believed to be little more than 100 feet. Its outlet is Grand Lake Stream, a shallow, rapid, gravelly stream, about 3 miles long, to which the salmon go in October and November to deposit their eggs. Comparatively few of the salmon of this lake resort to the streams tributary to it.

The operations with landlocked salmon necessarily differ from those with migratory salmon. Being at home in fresh water and having there their feeding-grounds, they continue to feed until the close approach of the spawning time, and hence they could not be penned up in the summer without some provision for an artificial supply of food, which would probably involve a great deal of expense and trouble. More-

over, the necessity of collecting breeding fish early in the summer does not exist, because they are at no time more congregated and easy to catch than at the spawning season.

Their capture is easily effected by stretching a net across the outlet of the lake and leading them through a tunnel-formed passage into an inclosure of netting. There happens to be at this point a wide surface of smooth bottom, with water from 1 to 3 feet in depth, affording an excellent site for spacious inclosures, not only for entrapping but for assorting and storing salmon during the spawning season. Nets are generally stretched across the stream (to keep the fish back in the lake) immediately after the beginning of the close season, September 15. The earliest of them begin to spawn before the end of October, but the actual inclosing of the breeding stock is deferred until the early days of November. The taking of spawn generally begins about November 6 and continues two or three weeks. Commonly by November 20 or 22 this work is completed, and the breeders are carried a mile or two up the lake and liberated.

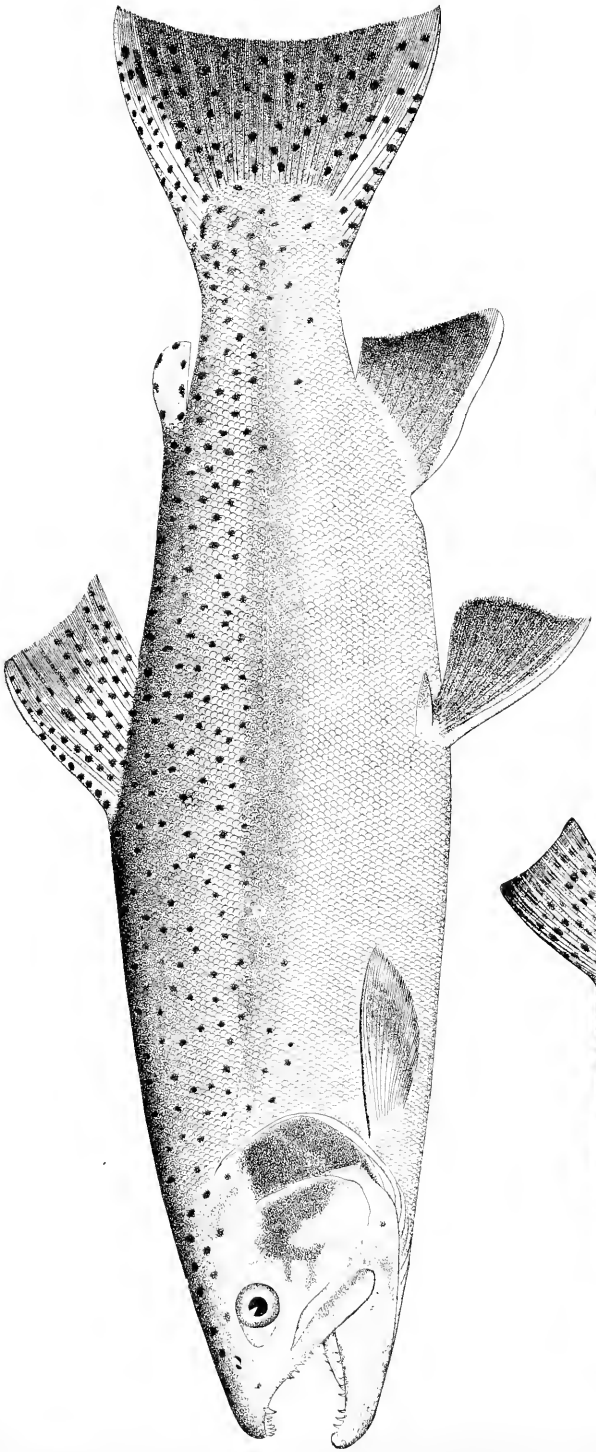
The method of manipulation is the same as at the Craig Brook station, and does not differ materially from that adopted by all the American breeders of *Salmonidæ*. The results in the impregnation of the spawn are not so uniformly satisfactory as with sea salmon. Ovarian disease seems more prevalent among landlocked than among migratory salmon. The occurrence of white eggs among the normally colored and healthy ones, as they are yielded by these fish, is very common, and occasionally the entire litter is defective. It is not improbable that some eggs are incapable of impregnation, though exhibiting no visible signs of disease. However, the general result is satisfactory, the ratio of impregnated eggs being from 93 to 95 per cent.

The facilities for developing and hatching the eggs at Grand Lake Stream are rather poor. No good site could be found by the side of the stream, no suitable brook could be found near enough to the fishing-grounds, and the neighboring springs lacked either volume or facilities for utilization. Of three hatcheries, two use spring water exclusively, and one of them lake or stream water exclusively. The lake water is preferred, but unfortunately it can only be used for the slow development of part of the eggs, circumstances connected with the floating of timber down the stream compelling the evacuation of that hatchery in March. The main hatchery is well located except that the water is from springs, and this unfavorable circumstance is well counterbalanced by the facilities for aeration, which are very good and very fully employed. The eggs are placed upon wire-cloth trays in stacks or tiers, ten deep, and arranged for a free horizontal movement in the water.

The egg shipments are made in January, February, and March, and sometimes in April. The eggs hatched are selected from those that have been retarded in development; the fry reach the age for liberation in June, when their natural food is believed to be abundant.

Experience at Green Lake has supplied some interesting data. Here we find the breeding-grounds of the salmon both in the affluents and in the effluent of the lake, but, unlike Grand Lake, mainly in the affluents. Great Brook, the largest tributary, is most resorted to, and on this stream is located a station for the propagation of this species. The most of the breeders are taken in a trap in the brook, which they readily enter when seeking to ascend to their natural breeding-grounds just above. The trap is constructed of wood, and close to it, also in the bed of the brook, are numerous pens of the same material, in which the fish are assorted and held during the spawning season. On the bank, snug by the pens, is the spawn-house, and a few rods away is the hatchery. The hatchery is supplied with water from Rocky Pond, the source of Great Brook, by a wooden flume 7,050 feet long, supported by wooden trestles, at some points elevated many feet above the ground. In cold weather the water cools off $1\frac{1}{4}$ degrees in passing down this flume; in warm weather it warms up $1\frac{1}{2}$ degrees. Though the summer temperature during the early years of the station was sometimes over 80° F. and some other species succumbed to the heat, the landlocked salmon endured it safely, and the only notable effect on them was that at 75° and upward the adults reared in the station ponds refused to eat.

As at Grand Lake Stream, among the adult wild salmon caught for breeding each year are many more females than males. In 1889 the proportion was 3 females to 2 males; in 1893 it was 9 to 4. The size of the Green Lake salmon is remarkable; the mean of 69 full-roed females in 1889 was 7.8 pounds in weight and 25.5 inches in length; the males the same year averaged 5 pounds in weight and 22.3 inches in length; one female weighed 11 pounds 9 ounces, and measured 30 inches; another, 11 pounds 6 ounces in weight, was $30\frac{1}{2}$ inches in length; one male, 31 inches long, weighed 13 pounds 8 ounces. The number of eggs yielded by the females is about 4,000 each.



SALMO IRIDEUS. *Rainbow Trout.* Upper figure adult male, lower figure immature fish.

THE RAINBOW TROUT.

DESCRIPTION OF THE FISH.

The body of the rainbow trout (*Salmo irideus*) is comparatively short and deep, and is more elongate in males than in females. The average depth is contained about three and four-fifths times in the body length. The short head, which is obtusely ridged above, is about one-fourth the total length. The mouth is smaller than in other species of *Salmo*, the maxillary reaching scarcely beyond the eye, which is rather large, and is contained five times in the side of the head. The caudal fin is distinctly but not strongly forked. On the vomer are two irregular series of teeth. The dorsal rays number 11 and the anal 10. In the typical species there are about 135 scales in the lateral series, with 20 rows above and 20 below the lateral line; in the several subspecies the number of rows of scales along the side is from 120 to 180. The color is variable, depending on sex, age, and character of water. Typical adult fish are bluish above, silvery on the sides, profusely and irregularly dark-spotted on the back and sides, the spots extending to the vertical fins, with a red lateral band and blotches and a nearly plain belly. The sea-run fish are nearly plain silvery. The chief distinguishing color characteristics of the varieties are in the number and position of the spots.

RANGE AND VARIATION.

The rainbow trout is not indigenous to eastern waters, its original habitat being the Pacific coast of the United States. It is especially abundant in the mountain streams of California. A few specimens, however, have been taken in salt water, and it is not unlikely that some find their way through the rivers into the sea.

The species is subject to considerable variation in form and color in different parts of its range, and the following varieties have received recognition by ichthyologists: The brook trout of western Oregon and Washington (*Salmo irideus masoni*), which rarely weighs as much as a pound and is locally abundant in the streams of the Coast Range from Puget Sound to southern Oregon; the McCloud River trout (*Salmo irideus shasta*), which attains a large size, is abundant in the streams of the Sierra Nevada Mountains from Mount Shasta southward, and is the rainbow trout which has received most attention from fish-culturists; the Kern River trout (*Salmo irideus gilberti*), which attains a weight of 8 pounds and is found only in Kern River, California; the noshee or nissuee trout (*Salmo irideus stonei*), which inhabits the Sacramento basin and reaches a weight of 12 pounds; the golden trout of Mount Whitney (*Salmo irideus aqua-bonita*), which inhabits streams on both sides of Mount Whitney, California.

In the extensive section of the West in which the fish abounds its name varies in different localities; red sides, mountain trout, brook trout, and golden trout, besides rainbow trout, are some of the popular appellations, while in the States east of the Mississippi River it is very generally called rainbow trout or California trout.

TRANSPLANTING.

The rainbow trout has been successfully transplanted in many of the mountain streams in different parts of the United States, where it grows and multiplies rapidly, as is shown by the many favorable reports. The best results, however, seem to have been obtained from plants made in streams of Michigan, Missouri, Arkansas, throughout the Alleghany Mountain ranges, and in Colorado, Nevada, and other Western States. It was introduced into eastern waters by the United States Fish Commission in 1880, but it is possible that specimens of it, or its spawn, had been brought east prior to that time by some of the State commissions or by private enterprise.

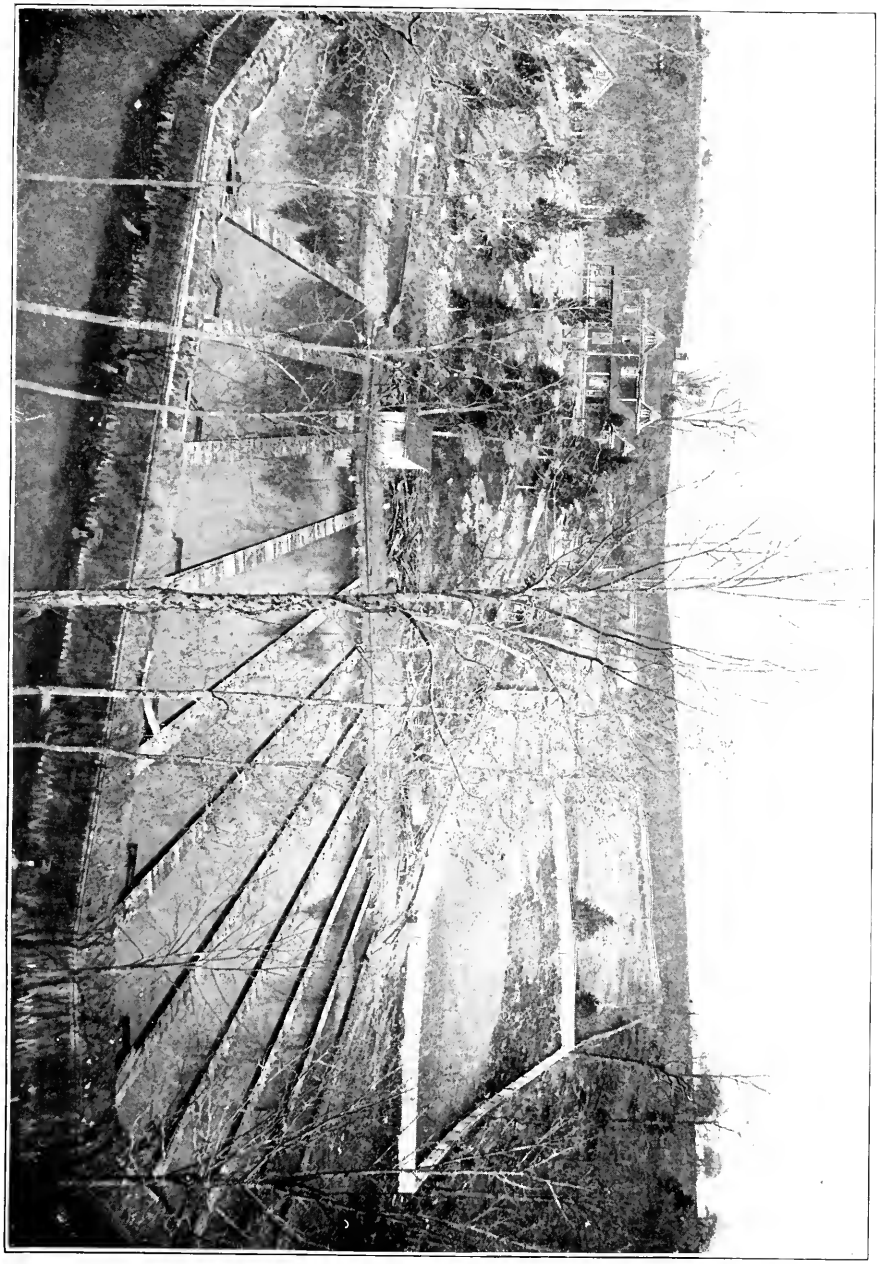
It is believed that this species will serve for stocking streams formerly inhabited by the brook trout (*Salvelinus fontinalis*), in which the latter no longer thrives, owing to the clearing of the lands at the sources of the streams, which has produced changed conditions in and along the waters not agreeable to the brook trout's wild nature. The rainbow is adapted to warmer and deeper waters, and is therefore suited to many of the now depleted streams which flow from the mountains through the cultivated lands of the valleys.

Rainbow trout differ widely from brook trout and other pugnacious fishes, in that they feed principally upon worms, larvæ, crustacea, and the like, and do not take readily to minnows as food. They should be planted in spring or early summer, when their natural food is abundant, as they will then grow more rapidly and become accustomed to life in the stream, and when worms, larvae, etc., are no longer to be found, their experience and size will enable them to take a minnow or anything that may present itself in the shape of food.

Fry should not be planted in open waters until they are several months old, and then not until the temperature of the streams begins to rise; but fish hatched in December and January can safely be planted in April and May.

SIZE AND GROWTH.

The size of the rainbow trout depends upon its surroundings, the volume and temperature of the water, and the amount of food it contains. The average weight of those caught from streams in the East is probably less than a pound, but some weighing 6¾ pounds have been taken. In the Ozark region of Missouri they are caught weighing 5 to 10 pounds. In some of the cold mountain streams of Colorado their average weight is not more than 6 or 8 ounces, but in lakes in the same State, where the water becomes moderately warm in summer and food is plentiful, they reach 12 or 13 pounds, fish of this size being from 25 to 28 inches long. In the Au Sable River, in Michigan, they



WYTHEVILLE STATION, VIRGINIA—NEW REARING-PONDS.

attain a weight of 5 to 7 pounds. In their native streams of California they are often caught ranging from 3 to 10 pounds, but average from 1 to 2 pounds. The largest specimen ever produced in the ponds at Wytheville, and fed artificially, weighed 6½ pounds, but many others in the same ponds weigh from 1 to 3 pounds.

The average growth of the rainbow trout under favorable artificial circumstances is as follows: One year old, from ¾ to 1 ounce; 2 years old, from 8 to 10 ounces; 3 years old, from 1 to 2 pounds; 4 years old, from 2 to 3 pounds. They grow until they are 8 or 10 years old, the rate diminishing with age. Some grow much faster than others under the same circumstances, but the rate of growth is largely a question of food, temperature of water, and extent of the range. In water at 60°, with plenty of food, fish 1 or 2 years old will double their size several times in a single season; while in water at 40°, with limited food, the growth is scarcely perceptible.

The rainbow, like the brook trout, will live in water with a comparatively high temperature if it is plentiful and running with a strong current, but sluggish and shallow water, even with a temperature of 70° F., is dangerous for brook trout. Rainbow trout will live in warmer water than brook trout, and are found in swift, rapid streams at 85° F., especially where there is some shade, but in ponds that temperature is dangerous even with shade and a good current. In its natural condition this trout is usually found in water varying from 38° F. in winter to 70° F. in summer, and in selecting a site for a trout hatchery spring water with a temperature of 42° to 58° is required.

The rainbow trout is a superior game fish, a vigorous biter, and fights bravely for liberty, though in the East it is somewhat inferior to the brook trout in these respects.

In the following pages is described the manner in which this fish is propagated artificially at Wytheville, together with the design and construction of the ponds and apparatus, and such other information is given as is suggested by experience at this station. It may be observed that the methods would be equally applicable to the propagation of the brook trout.

SPAWNING-PONDS.

In constructing ponds, one of the first considerations is to place the fish absolutely under the control of the fish-culturist, that he may be able to handle them without delay or inconvenience. At Wytheville they are constructed entirely of wood, about 15 by 50 feet and 3 to 3½ feet deep, and shaped as shown in plate 21, and have been found very satisfactory. Excellent water circulation is obtained in all parts, and there are no corners for refuse to lodge in. The bottom of the pond is built with a gradual elevation, in the direction of the upper end, of 2 inches in the entire length of the pond. This makes it practically self-cleaning; nearly all of the foul matter will pass off and any remainder can be disposed of by drawing the water down low for a short period and then flushing the pond with fresh water. This method obviates the necessity of handling the fish, which is very important, especially when near the spawning time.

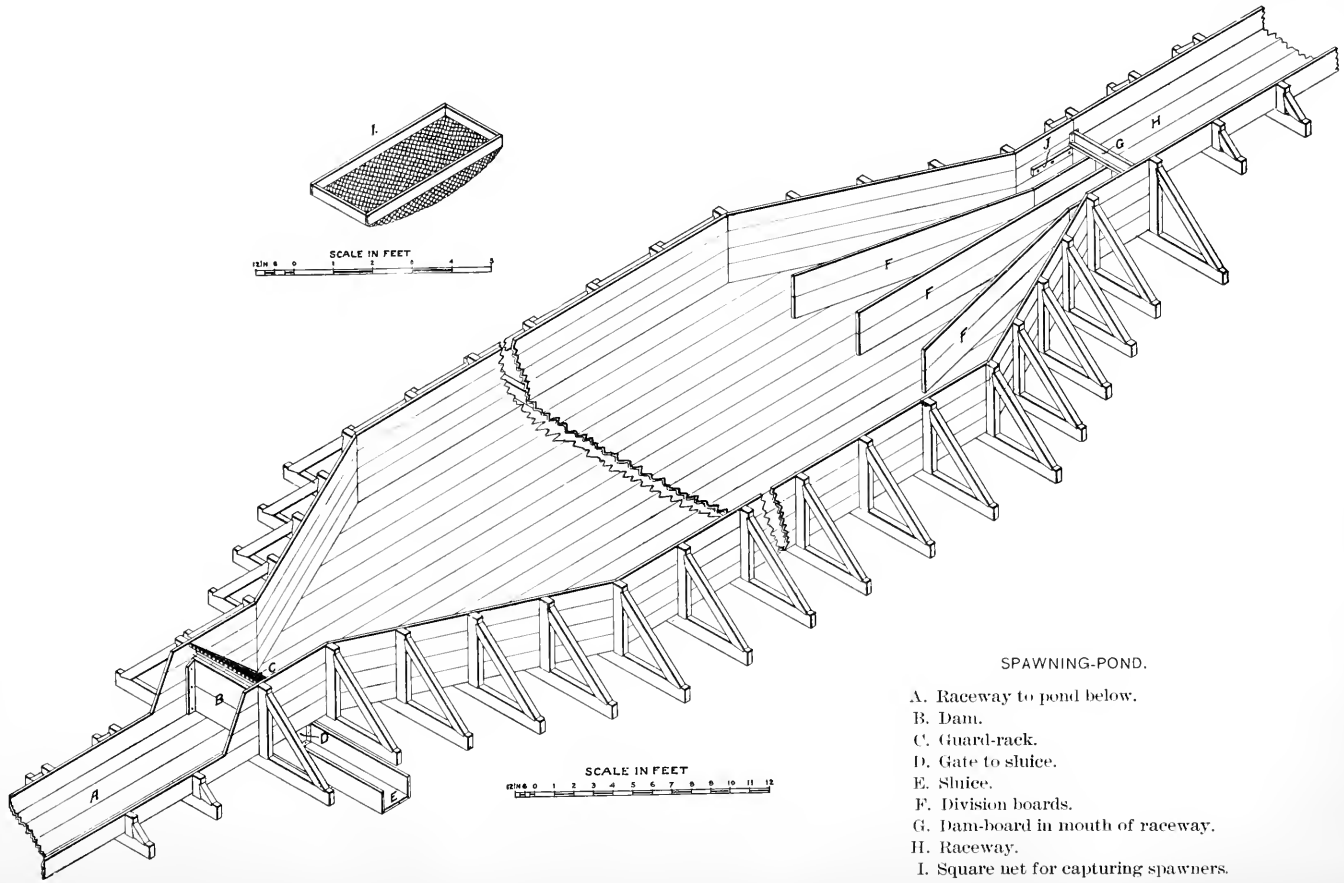
A guard-rack made of thin, narrow slats is arranged on an incline of about 45°, as shown at C. If the water is to be used again in ponds below, a receiver is built underneath the bottom of the pond at the lower end, between the foot of the guard-rack and the dam-boards, and the floor of the pond immediately over the receiver is cut away and fitted with a grating. This allows matter to fall through the receiver and from there it is washed through the sluiceway, which taps the receiver by drawing the gate shown at D. The sluiceway, E, is covered and leads off to a general waste-ditch.

The pond is provided with a spawning-race about a foot deep, 4 feet wide, and 25 feet long, placed at the upper end of the pond, as shown at H. Three division boards (shown at F), about 12 feet long and of suitable width to come within 1 or 2 inches of the surface of the water when the pond is filled, are firmly fixed at the bottom. The object of these boards is to form four avenues leading to the raceway, so that one or two pugnacious fish can not command the approach and keep back spawning fish inclined to enter. There is a dam across the raceway about 4 inches high (shown at G) for the purpose of bringing the water to that depth in the lower end, so that when the trout enter they will find sufficient water in which to swim freely, and not be inclined through fear to return to the pond.

The water in the pond is of sufficient depth to bring its surface within 6 inches of the top of the dam in the raceway, which will give the fish, in entering the raceway, a jump of 7 inches, allowing 1 inch for the depth of water on the dam in the raceway. This distance has been found more satisfactory than any other, and spawning fish alone will go up. If a jump of less than 7 inches is given, other fish can enter the raceway without much exertion, and will ascend and disturb the breeding fish, which, when spawning, should be kept strictly by themselves.

There is no rule regarding the supply of water that applies to a spawning-pond at all times and in all places. It is necessarily governed by the temperature of the water, size and shape of the pond, size of the fish to be supported, the amount of shade, etc. For a pond such as has been described, where water is plentiful, at least 200 gallons per minute should be provided, with not less than 75 gallons per minute as a minimum, even where the temperature is from 50 to 55 degrees and all other conditions are favorable. While the former amount is not absolutely necessary for the support of the fish, it insures the pond being kept clean and the fish are more inclined to enter the raceway at spawning time. In order to maintain an even temperature in the pond the earth is banked against the sides and ends, covering the framework shown on plate 21, and the embankments are made broad enough on top to admit of a good footway around the ponds.

Such a pond as this can accommodate from 1,000 to 1,500 breeding fish. Fish must not be overcrowded, and in estimating the capacity of



SPAWNING-POND.

A. Raceway to pond below.
B. Dam.
C. Guard-rack.
D. Gate to sluice.
E. Sluice.
F. Division boards.
G. Dam-board in mouth of raceway.
H. Raceway.
I. Square net for capturing spawners.

a pond several modifying conditions must be considered, such as the size of the fish, water supply, temperature, and shade. In stocking the spawning-pond a good proportion is two females to one male. The breeding stock is selected carefully every year; only sound and perfect fish are retained for the next season, and the blind and emaciated fish of both sexes are destroyed.

TAKING THE SPAWN.

The spawning season varies with the locality and the temperature of the water. It is usually two to four weeks later in the streams than where the fish are kept confined in spring water. In the ponds at Wytheville the spawning fish may be found any time after the 1st of November; the season is well started by November 15, and generally closes about the 1st of March. December and January are the best months. In California the season extends from the 1st of February to May, and in Colorado begins early in May and continues until July.

The natural nests of these fish are made on gravelly bottoms, and are round or elongated depressions about the size of a dinner plate. After the eggs have been deposited and fertilized they drop between the pebbles of the nest, where they lie protected until hatched.

Where spawning-ponds are provided with suitable raceways the fish will ascend from the ponds into them, seeking a place to make their nests, and may then be taken out and stripped of their spawn. To take the fish from the raceway, a square net (I, plate 21) is dropped in on the cleats nailed against the side walls in the approach, shown at J, the dam in the mouth of the raceway is raised, and the fish driven back into the net. The net is then lifted out of the water, and if it contains too many fish to handle conveniently a landing-net is used to take out part of them before the square net is moved. The ripe fish are then placed in tubs or other vessels provided for the purpose. If too many fish are put in the tub at one time they become restless and sick before they can be stripped of their spawn.

There are two methods of taking and impregnating the spawn of fishes, the "wet" and the "dry" methods. By the "wet" method the eggs are taken in a pan containing sufficient water to cover them and allow them to mix freely with the milt, which is immediately added. After the contents of the pan have been stirred for a few seconds with a feather, the eggs are set aside and left undisturbed during fertilization. The "dry" or "Russian" method is now in general use; the eggs and milt are taken in a moist pan and it makes little difference which is taken first, but one should immediately follow the other, and the contents of the pan be thoroughly mixed.

After the eggs and milt have had time for contact, and before the eggs begin to adhere to the bottom of the pan, water is added to the depth of about an inch, the eggs being kept in gentle motion, by turning the pan, to prevent adhesion. After 2 or 3 minutes the milt

is poured off and clear water is put in the pan, in which the eggs are allowed to remain until they separate, which will be in from 15 to 45 minutes, depending on the temperature of the water. It is preferable to take the eggs to the hatchery before the milt and water are poured off, and there rinse them off and place them directly on the hatching-trays (previously arranged in the troughs) and then allow them to separate. In freezing weather it is advisable to strip the eggs in water or to use two pans, one set in the other, with water in the bottom pan to prevent the eggs from being chilled.

In taking spawn the manipulation of the fish without injury is a very delicate and exacting task, full knowledge of which can only be acquired by experience, as it is difficult to squeeze the spawn from the fish without injuring or even killing it. In taking hold of the fish in the spawning-tub the operator catches it by the head with the right hand, the back of the hand being up, and at the same time slips the left hand under the fish and grasps it near the tail, between the anal and caudal fins. A fish caught in this way can be easily turned over as it is brought out of the water, so that its abdomen is up and in the proper position for spawning by the time the spawning-pan is reached. If the fish struggles it must be held firmly, but gently, until it becomes quiet, and when held in the right position it will struggle only for a moment. A large fish may be held with its head under the right arm.

When the struggle is over the right hand is passed down the abdomen of the fish until a point midway between the pectoral and ventral fins is reached, then with the thumb and index finger the abdomen is pressed gently, and at the same time the hand is slipped toward the vent. If the eggs are ready to be taken they will come freely and easily, and if they do not, the fish is put back in the pond until ready to spawn. If the eggs come freely from the first pressure the operation is repeated, beginning at or near the ventral fin.

After the first pressure has been given, by holding the head of the fish higher than the tail, all of the eggs that have fallen from the ovaries and are ready to be expressed will fall into the abdomen, near the vent, so that it will not be necessary to press the fish again over its vital parts, the eggs having left that portion of the body. All of the eggs that have fallen into the abdomen below the ventral fin can be easily ejected without danger of injury to the fish, caused by unnecessary pressure over its important organs after the eggs have left that part of the body. If these directions are judiciously and carefully followed but little, if any, damage will result; and, as an illustration, it may be mentioned that fish have been kept for 14 years and their full quota of eggs extracted each season during the egg-producing term, which is normally from 10 to 12 years. The male fish is to be treated very much in the same manner as the female, except the milt must not be forced out, only that which comes freely being taken.

After stripping, the fish are not returned to the spawning-pond, but spent females are placed in one pond and the males in another. The

INTERIOR VIEW OF WYTHEVILLE HATCHERY, SHOWING MEN PICKING OUT DEAD EGGS.

males are very pugnacious at this season, and sometimes fight for an hour or more at a time, until they are entirely exhausted; they run at each other with open mouths, lock their jaws together, and in that position sink to the bottom of the pond, where they lie for a short time, each holding the other in his grasp until rested, when they rise and resume the combat. As their teeth are abnormally long, they scar each other and even bite pieces of skin and flesh from the sides of their antagonists.

The males are good breeders at two years old, but very few females produce eggs until the third season, when they are from 30 to 36 months old. At Wytheville hatchery about 1 per cent of the females spawn at 2 years of age; about 50 per cent at 3 years, and about 85 per cent each season after that. About 15 per cent of the fully matured females are barren each season. It was at one time thought that the same individuals were barren each year, but experience has shown that such is not the case, as fish which were barren one season have been held over, in a separate pond, until the following year, when a large portion, if not all, produced eggs. This sterility may be the result of injuries which were received the previous season, during the progress of spawning.

EGGS.

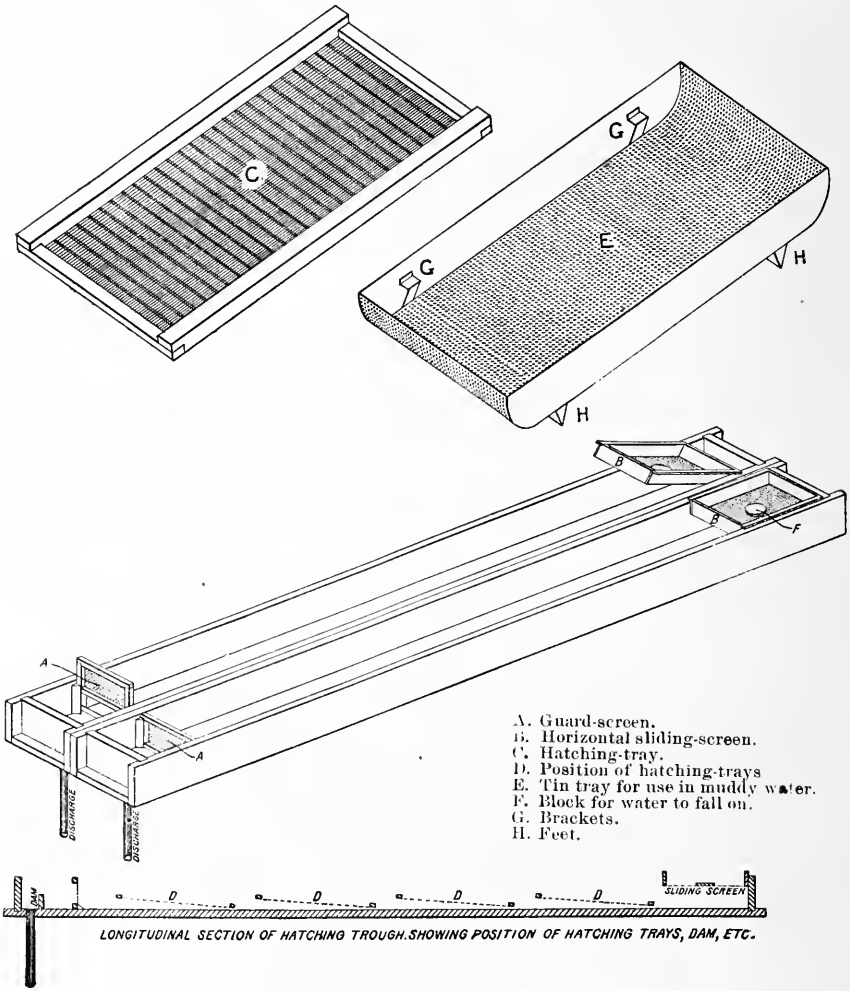
The number of eggs produced in a single season depends upon the size and age of the fish. The maximum from one 3 years old, weighing $\frac{1}{2}$ to $1\frac{1}{2}$ pounds, is from 500 to 800; from one 6 years old, weighing 2 to 4 pounds, it is 2,500 to 3,000. The eggs vary in size from $4\frac{1}{2}$ to 5 eggs to the linear inch, and are of a rich cream color when first taken, changing to a pink or flesh color before hatching.

THE HATCHING-TROUGHS AND TRAYS.

The eggs are incubated on trays placed in troughs of various sizes and shapes, which at Wytheville are set in pairs, as shown on page 68. They are made of the best pine lumber, dressed to $1\frac{1}{2}$ inches thick, and are 15 feet long, 14 inches wide, and 8 inches deep. Fourteen inches from the lower end inside is a guard-screen of perforated tin or wire mesh, fastened on a frame exactly fitted across the trough. Tin with perforations of $\frac{1}{16}$ inch for very young fry, and larger ones as the fish grow, is preferable to wire. The screen is arranged to slide vertically between beveled cleats, that it may be kept clean easier. A plain board, $3\frac{1}{4}$ inches wide, is placed 4 or 5 inches from the lower end of the trough to serve as a dam.

In the upper end of the trough horizontal screens (B, page 68), made of perforated tin, are used. These are so constructed that they can be slipped forward or raised up (as shown in the illustration) in feeding the fry or cleaning the troughs, and the water falling on a small wooden block in the center of the screen is thoroughly aerated before entering the trough. This arrangement possesses many advantages over the old method, where the screens were vertical, or nearly so, as it permits the

fish to ascend to the head of the trough and receive the water as it falls from the screen, which is very beneficial. Its use not only keeps the fry clean even in muddy water, but also reduces the loss of fry from suffocation in the early stages, caused by their banking around the vertical screens, and obviates the necessity for trough covers to prevent jumping, as trout rarely jump where the horizontal screen has been adopted.



Hatching-troughs, Guard-screen, etc.

Hatching-trays (C), made about twice as long as wide, i. e., 28 by 13½, are convenient to handle and adjust in the troughs. The sides of the frame are made of good pine lumber, dressed, 1 inch square; the ends are dressed ½ by 1 inch, and are cut into the sides to form a smooth surface on the bottom for the wire filling. The wire used on the trays is woven with 8 threads to the inch, with a mesh ⅞ inch long, and should be well galvanized after it is woven, in order to prevent rusting at the laps.

Four hatching-trays are placed in each trough and are secured by keys or wedges, and should be from 1 to 2 inches lower at the end next to the head of the trough, as shown at D, D, D, D, page 68. If placed in this way, each tray will hold from 12,000 to 15,000 eggs with safety. Muddy water during the hatching season necessitates the use of a tin tray with a perforated bottom (shown at E, page 68), which is $13\frac{3}{4}$ inches wide and 32 inches long. This sets inside of the hatching-trough on feet raising it an inch above the bottom of the trough. The hatching-tray containing the eggs is placed inside and rests on the brackets shown at G. The fish, as they hatch out, fall from the hatching-tray upon the perforated bottom of the tin tray, and by their movements work the sediment through, leaving them on a clean bottom and in no danger of being smothered. The tin trays are also useful in counting fish, or in holding small lots of fish of different species in the same trough. Where supplementary trays are not used, the fry fall directly into the troughs.

Troughs 15 feet long will admit of four hatching-trays in a single row, each of which will safely carry 12,500 eggs, making 50,000 to a trough; this is enough to work easily, but if it is necessary to make more room a double row of trays may be put in, one tray resting on the top of the other. Thus the trough could contain 100,000 eggs as its full capacity. The troughs will carry this number up to the time of hatching by placing the trays lower at one end than the other, as previously described.

When the hatching stage arrives, two trays of 12,500 eggs each are as many as should be left in one trough; with this number, by using the horizontal sliding-screen in the upper end, there is but little danger of the alevins congregating and smothering in any part of the trough. If it is necessary to hatch a much larger number than this in one trough, the sliding-screen is so arranged that the water falls well up against the end of the trough. This is done by raising the screen and turning it back against the reservoir, or by putting in a wedge-shaped block for the water to fall upon, turning the thin side of the block toward the upper end of the trough. Fifty thousand trout have been hatched in one trough prepared in this way without loss from suffocation, but it is not advisable to hatch such a large number together.

The amount of water necessary for hatching and rearing depends upon the temperature and the manner in which the water is applied. The water should receive as much aeration as possible before entering the compartments containing the fish and eggs. At Wytheville, where there is an even temperature of water of 53° in the hatchery, about the following quantities are used in the troughs containing fish and eggs:

100,000 eggs during incubation, $12\frac{1}{2}$ gallons per minute.
100,000 fish hatching to time of feeding, 30 gallons per minute.
100,000 fish from 1 to 4 months old, 50 gallons per minute.
100,000 fish 4 to 6 months old, 100 gallons per minute.
100,000 fish from 6 to 12 months old, 200 gallons per minute.

These amounts are ample, and probably even half would suffice if it were necessary to economize in the use of water. In rearing-ponds more water is required, as the circulation is not so good and the outdoor exposure causes the temperature to rise. If water is plentiful, double the amounts stated would be advisable for pond-culture.

During the last two seasons at Wytheville 80 to 85 per cent of the eggs taken produced fish, of which about 70 per cent were raised to three months old and 55 per cent to yearling fish. The loss in eggs was almost entirely due to failure in impregnation, very few being lost from other causes.

CARE OF EGGS AND FRY.

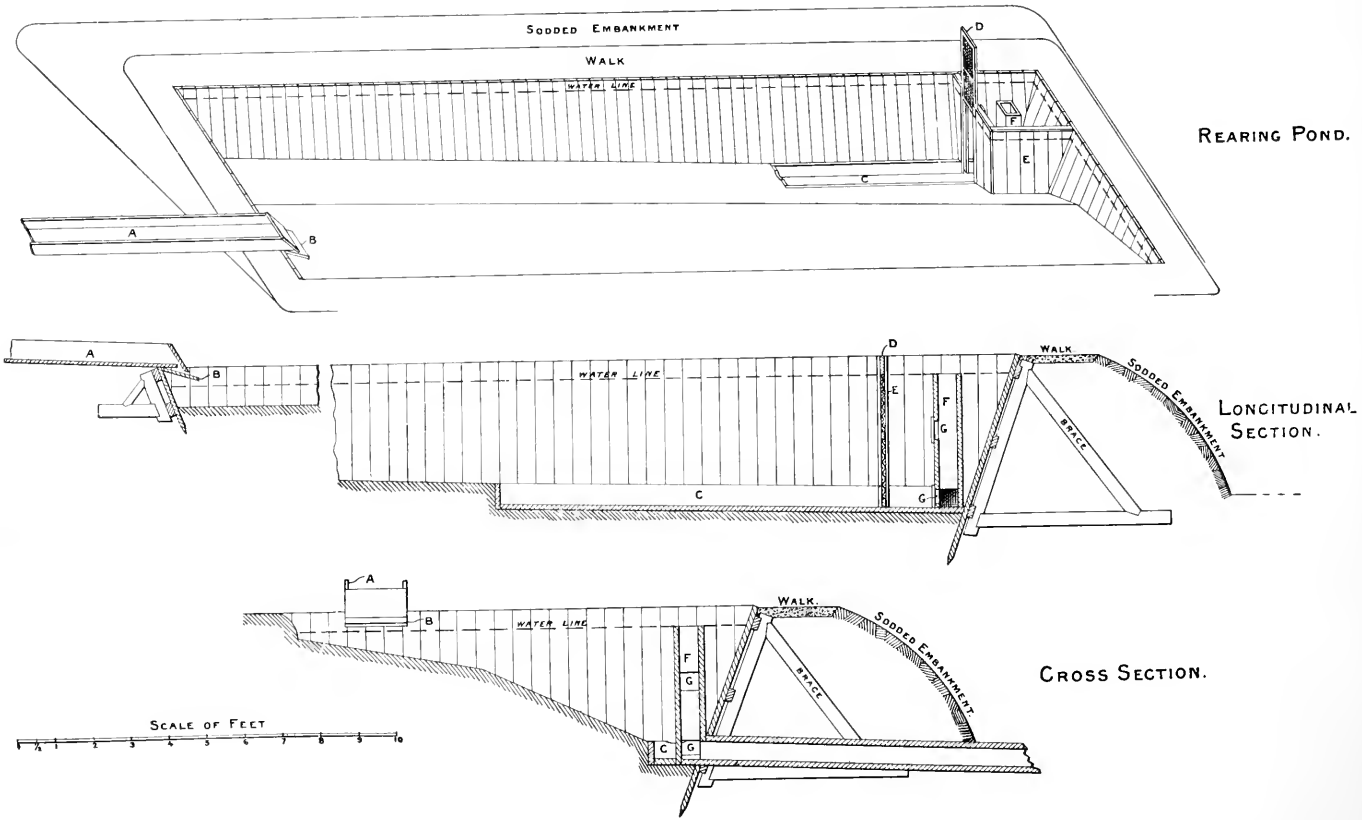
After the eggs are placed on the trays, the only attention necessary until the hatching begins is to keep them clean; the dead eggs, which may be known by their turning white, must be picked out at least once each day. After the eye-spot can be plainly seen it is well to run a feather through the eggs for the purpose of changing their position on the trays, and to disclose any foreign matter or dead eggs that may be hidden underneath. The greatest care should be exercised in handling the eggs at any time, particularly from the first or second day after collection up to the appearance of the eye-spot, and then only when absolutely necessary. During this period, the eggs are very delicate, and even passing a feather among them may cause a heavy loss.

The time required for hatching depends mainly upon the temperature of the water. Rainbow trout eggs will hatch in water at 50° in from 42 to 45 days, each degree colder taking 5 days longer, and each degree warmer 5 days less; the difference increases as the temperature falls and diminishes as it rises.

After the fry hatch they require but little attention until the umbilical sac is absorbed and the time for feeding arrives. They are examined each day, and the dead fish and decayed matter removed from the troughs, which are kept perfectly clean, and if possible provided with a thin layer of coarse white sand on the bottom, to keep the fish in healthy condition. As the fish grow they should be thinned out in the troughs, from time to time, as their size may require. When they first begin to feed, 12,000 to 15,000 fish to the trough are not too many; but by the time they get to be 1¼ to 1½ inches long they must be divided into lots of 8,000 to 10,000 to each trough; while with fish averaging 3 inches in length, 3,000 to 4,000 are as many as one trough will accommodate. It is advisable to give as much room as is practicable.

REARING-PONDS.

Ponds for rearing trout are from 8 to 12 feet wide, and of any desired length up to 60 feet, which, for convenience in drawing them off and in feeding the fish, is about the extreme limit. The size, shape, and arrangement of the ponds must depend upon the ground on which they are to be constructed. If practicable, it is best to build them on a



REARING POND.

A. Supply-trough.
B. Apron.
C. Receiving-trough.
D. Guard-screen.
E. Crib around standpipe.
F. Standpipe.
G. Holes in standpipe.

hillside, one above the other, with earth and piling embankments on the lower sides and at the ends. A pond of this kind is shown in plate 23, and is the one here described. Various materials may be used for damming the water. The embankments may be made altogether of earth or lined with stone, brick, cement, or timber, according to circumstances. Where the ground is of a porous or loose formation it is necessary to use piling or cement for the inside of the embankments and possibly cement for the bottoms, but earth bottoms are best where the nature of the ground permits. The water enters the pond at one end and discharges from the lowest opposite corner. The bottom is graded as shown in the cross-section, plate 23, with a slope toward the outlet, so that when all the water is drawn out the fish are led into the receiving-trough (C), the top of which is flush with the earth bottom in that part of the pond.

The outlet for the water is an L-shaped pipe, shown at F, and is placed in the corner of the pond, the long end passing through the piling and underneath the pond embankment; the short end, called the standpipe, stands close to the inside corner of the pond, in an upright position. The standpipe has two or more holes cut through (G) on the side next to the receiving-trough, to let the water pass out in drawing down the pond. The size of these holes is in proportion to the size of the standpipe, which, in turn, is governed by the size of the pond. The holes may have blocks of suitable size tacked over them to allow the pond to fill with water, or, what is more convenient, covered with blocks arranged to slip down in grooves, one block resting on the other. Surrounding the standpipe is a crib, the front of which is 15 inches or more from the pipe and contains an opening for a guard-screen, which is 14 to 16 inches wide and made with copper or galvanized wire cloth, the size of the mesh depending on the size of the fish in the pond. In the bottom of the pond is a receiving-trough (C) for the fish, built in proportion to the size of the pond; 10 feet long, 16 inches wide, and 6 inches deep is a satisfactory size for a pond like the one described. This trough extends to and connects with the standpipe, and the guard-screen is arranged to fit down on the inside. Every part is made secure, to prevent fish from escaping when drawing off the water. The supply-trough or pipe is arranged to keep the fish from jumping into it from the pond, as shown at A.

STOCKING THE REARING-PONDS.

The rearing-ponds at Wytheville are stocked gradually, 500 to 1,000 fish being placed in the pond and trained to take food before more are added, as that number can generally find enough natural food to subsist upon until they learn to take artificial food. When they have been accustomed to hand-feeding another 1,000 fish are added, and in about ten days 2,000 more, this practice being continued until the pond is stocked with the desired number. When fish are first released in ponds

they are wild and run away from the food given them; hence the necessity of teaching a few fish to eat before more are added. The number of fish that a pond of a given size can support depends upon the amount of water and shade and the temperature of the former. Ten thousand fish are ample for a pond 10 by 50 feet, with water deepening from 3 inches to 3 feet.

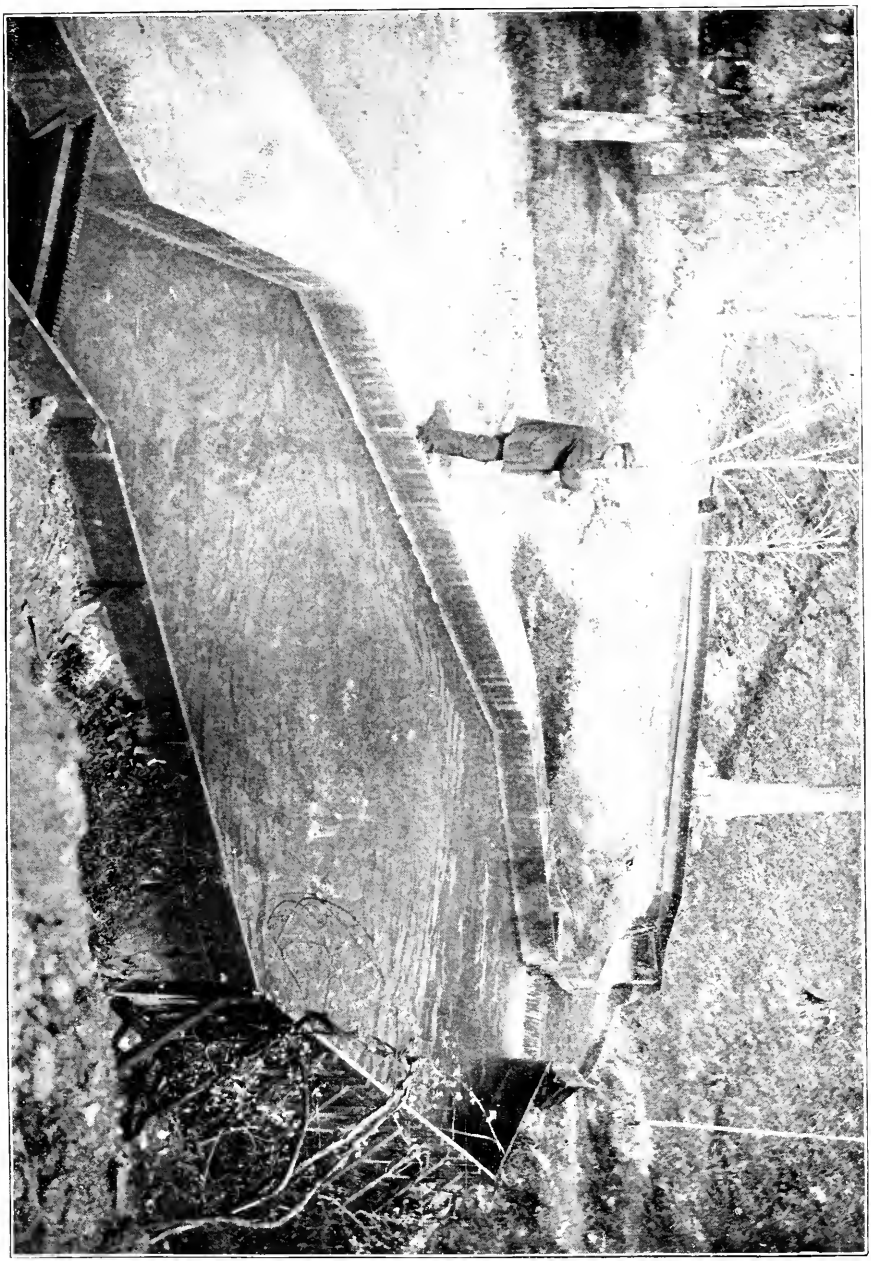
FOOD FOR FRY.

Beef or sheep liver, ground or chopped to a pulp, seems to be the most satisfactory artificial food for young trout. Fresh, hard-boiled eggs, grated fine, are good, but expensive. Efforts have been made to produce a natural or living food, such as insect larvæ and small crustaceans, and this may yet be accomplished for late spring and summer feeding, but for feeding the fry during the first three or four months of their lives, which is in the winter season, there is nothing better than liver. Shad and herring roe, put up in sealed tin cans, have been used to a limited extent with satisfactory results, and it is believed that they will furnish a wholesome and natural diet.

The manner of feeding young fry is very important, as the losses from improper feeding are greater than from all other causes combined. If there is undue haste the water becomes polluted, or the food is so distributed that some fish are prevented from getting their proper share. Polluted water is very injurious to the young fish, being apt to produce inflammation of the gills and a slimy, itching condition of the skin, which often causes heavy mortality.

The fry are ready to take food as soon as the sac is absorbed, the time required for this depending upon the growth of the fish, which is governed by the temperature of the water. Where the temperature is regular at 53° they will take food in about 30 days after hatching, and the time to commence feeding may be closely determined by watching the movements of the fish. Before the sac is entirely absorbed they will begin to break up the school on the bottom of the trough and scatter through the water, rising higher and higher from the bottom each day, until they can balance themselves gracefully in a horizontal position, all heading against the current and swimming well up in the water. By dropping some small bits of cork or the nap from red flannel on the surface of the water it can be determined if they are ready for food; if they strike at the pieces as the current carries them down it is evident they are hungry.

The liver is prepared by chopping it very fine and, if necessary, mixing it with water, in order that it may be distributed evenly. It should be given to the fish by dipping a feather into the liver and gently skimming it over the surface of the water. After the fish grow to be $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long they begin to take up the food that settles on the bottom of the trough; it is then not necessary to mix the food with water, and it can be given by hand. The young fry are fed five or six times a day and the food given slowly and sparingly. After they



WYTHEVILLE STATION, VIRGINIA.—SPAWNING-POND, SHOWING RACEWAY.

learn to take their food from the bottom of the trough it is necessary to feed them only three times daily, but more food must be given at each meal.

FOOD OF ADULT FISH AND YEARLINGS.

In domestication the rainbow trout is preferably fed upon a meat diet altogether, if it can be had plentifully and sufficiently cheap; otherwise a mixture of liver and mush may be used advantageously. The mush is made by stirring wheat shorts or middlings in boiling water until the mixture becomes thick; it will keep for several days, even in warm weather, if put in a cool place. The liver is ground or chopped fine and mixed thoroughly with the mush in any desired proportion up to four-fifths of the whole, but it is better to mix only as needed. This mixture has been used satisfactorily for many years.

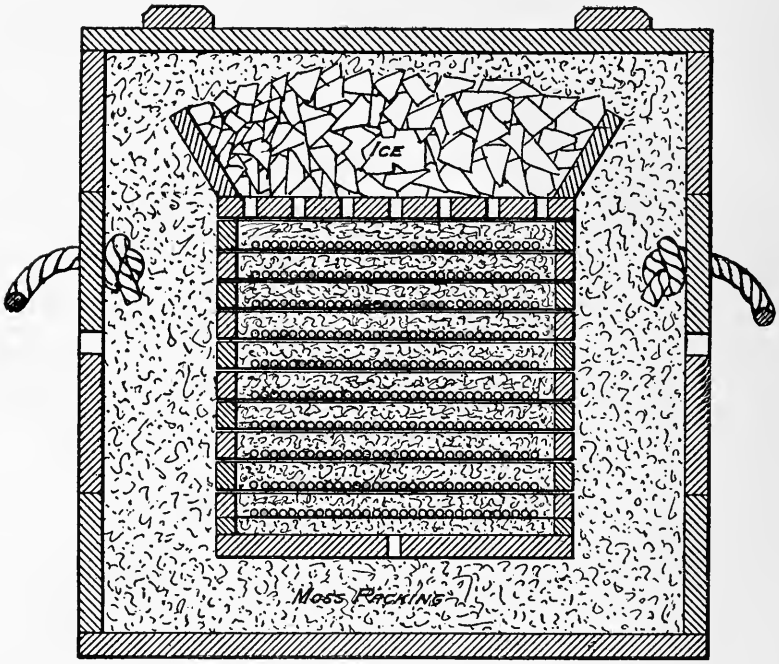
A meat-chopper may be obtained for grinding liver which will do the work in an excellent manner, leaving no strings or gristly chunks to choke the fish. There are several sizes of the machine made, with extra perforated plates having different-sized holes, from one-twelfth to one-fourth of an inch in diameter, so that the meat may be prepared coarse or fine, to suit the size of the fish to be fed. For small fry it is necessary to use the plate having the smallest holes and to grind the food over several times until fine enough to use.

The practice of throwing food into the pond in handfuls causes the fish to come together in great numbers and in a violent manner; and struggling with open mouths to get a bite of the food, they often hurt each other, injure one another's eyes, sometimes even plucking them from the sockets. This is probably one of the main causes of blindness among pond-fed fish.

The most approved method of feeding is to walk along the pond its entire length to the upper end (the fish will soon learn to follow to that point), then scatter a handful of food along the surface of the pond so that it will fall to pieces. The fish follow and take up what has been thrown out and then return to watch for the next handful, and the operation is repeated until sufficient food is given. This manner of feeding induces all the fish to head in the same direction while eating, thus reducing the danger of injury.

The amount of food for a given number of trout depends upon the size of the fish and the temperature of the water, as fish will not take food as freely in water of a low temperature as in warmer water. With water from 50° to 60° a daily ration for 1,000 yearling fish ranging from 3 to 5 inches in length is about $\frac{3}{4}$ of a pound; while for the same number, 8 to 12 inches long, about 12 pounds per day are required.

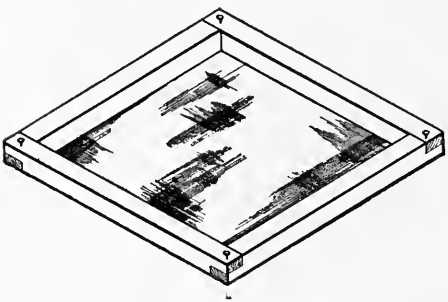
As the fish increase in size the amount of food should be increased proportionately. They are fed twice a day at regular hours, morning and evening, giving half of the daily allowance each time. This keeps them in a thrifty and growing condition.



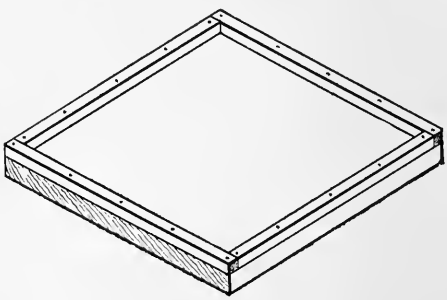
Cross-section through Box after it has been packed and closed.

PACKING EGGS FOR SHIPMENT.

In packing trout eggs for shipment they are usually placed on trays and packed in wet moss and the eggs divided into from five to ten equal parts, according to the size of the shipment, using trays of suitable size to hold each part. If 30,000 eggs are to be shipped, ten trays are used large enough to contain 3,000 eggs each; if 15,000 eggs, ten trays



A. Egg-tray.

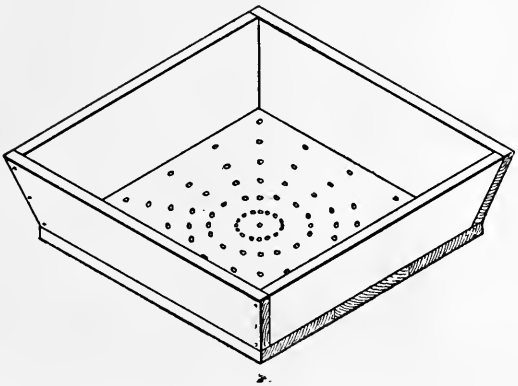


B. Foundation-board.

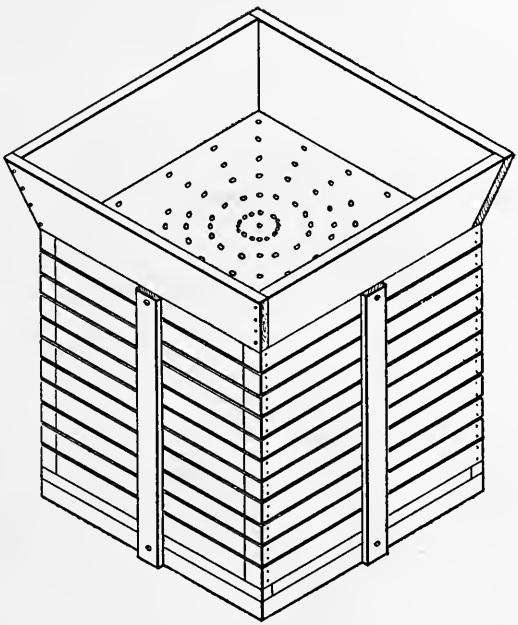
containing 1,500 eggs each; 10,000 eggs, eight trays of 1,250 each, etc., and if over 30,000 eggs are to be shipped the shipment is made in more than one lot. In a package of more than ten trays, especially if the trays are large, the eggs on the lower trays are liable to be crushed

by the weight above, and if less than five trays are used in a shipment the package is liable to become dry, and the eggs reach their destination either dead or in a shriveled condition.

The frames of the trays are made of light, soft wood dressed to $\frac{5}{8}$ by $\frac{7}{8}$ of an inch, with a soft canton-flannel bottom tightly stretched and well tacked on. The trays are made large enough to contain their proportion of the eggs, with an allowance of $\frac{3}{4}$ of an inch between the eggs and the frame of the tray. A foundation-board (B) is made with the same outside dimensions as the tray, with a strip nailed around the edge on the upper side to form a cushion of moss for the bottom tray. A hopper for ice (C) is used on the top tray. The outside case (E) is made 7 to 8 inches larger on the sides (inside measure) and 5 inches deeper than the outside dimensions of all the trays after they are cleated together, including the hopper and the foundation-board, as shown at D.



C. Ice-hopper.



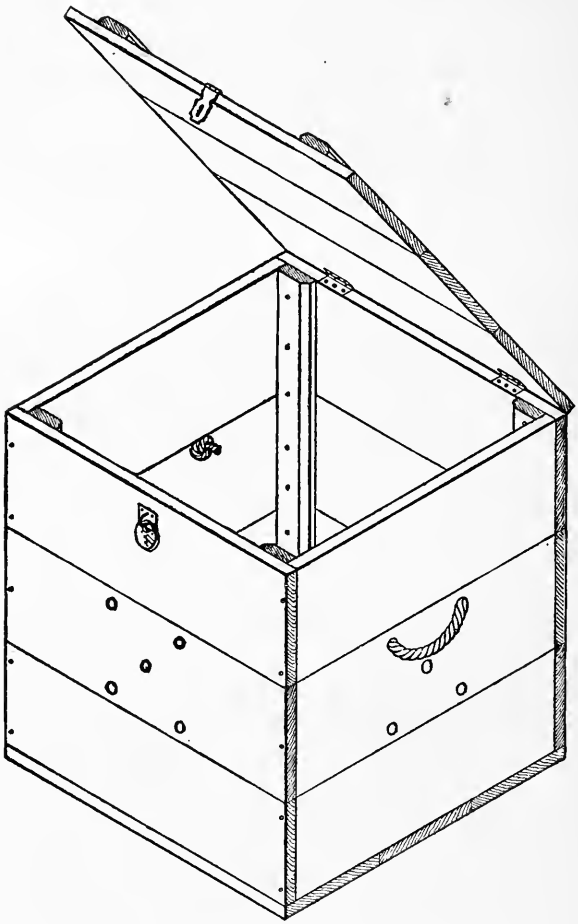
D. Egg-trays packed and cleated.

The trays having been prepared, the eggs are selected, those being taken which show eye-spots and are not too old to reach their destination before the time for hatching. Allowance is made for changes in temperature on the road which would cause them to hatch too soon.

The eggs are taken from the hatching-trays in pans, well cleaned of all sediment, and given a slight concussion by allowing water to fall on them from a small spout or sprinkling pot, which causes the dead and unfertilized eggs to turn white, when they are carefully removed. The

eggs are then accurately weighed or measured (1 ounce may be weighed and counted, or the eggs for one tray counted and then weighed) and the required number placed in a single layer in the middle of the tray, leaving an empty space all round next to the frame.

The trays are then placed one above the other on the foundation-board, after each is covered with a piece of mosquito netting, which should be at least 2 inches larger each way than the tray, and the



E. Outside case.

tray is filled with wet moss, the part immediately over the eggs in a loose manner, the empty space around the eggs packed tight. This gives support to the next tray above and prevents the eggs from coming in contact with the wood and becoming dry and shriveled.

After all the trays are thus arranged the hopper is placed on top and the whole cleated together, as shown at D. They are then ready to be placed in the box or outside case (E). Dry sphagnum moss is placed

in the bottom of the box to a depth of about 3 inches and the crate of trays placed as near the center of the box as possible. The sides are well packed to hold it firmly in position, and when the top of the hopper is reached with the packing it is well filled with ice, the remaining space in the box being filled with moss. Wet moss or wet packing of any kind should never be used for the cushion around the egg-crate, as it does not preserve an even temperature and is liable to freeze solid if exposed to a low temperature in transit. A cross-section of the box thus packed is shown on page 74.

The box containing the eggs should be provided with handles to facilitate moving during transportation, in order that the liability to injury from jarring or concussion may be reduced. For a long journey the lid of the box is provided with hinges and hasp and staple, so that the ice may be easily renewed. Eggs packed as described above have been shipped with safety to all parts of the United States and to foreign countries.

DISEASES OF FRY AND ADULTS.

The most common diseases of trout fry are the inflammation of their gills and a slimy skin disease, which may be caused by impure water; the food itself may produce it, especially if stale liver is used, but it generally follows fouling of the water while feeding. By watching the movements of the fish, the symptoms of disease can generally be detected before it reaches an alarming stage. If the gills are affected the fish will usually swim high in the water in an uneasy, restless manner, as if gasping for breath, and when this is observed the gills must be examined to see if they are becoming inflamed and swollen. If a skin disease is attacking the fish, they generally indicate it by rubbing themselves on the bottom of the trough or against anything that may be convenient, or by diving down and giving themselves a quick, twisting motion against the bottom of the trough. If the progress of disease is not promptly checked, it will soon reach a stage where nothing can be done, and the fish grow weaker every day until they begin to die in alarming numbers. One of the best remedies for both diseases is salt sprinkled through the water after the ponds are drawn low, and for a bad case of skin disease a half pint of salt for every gallon of water in the trough is used, or about that proportion. The fish should be watched closely and allowed to remain in the salt water until they become restless and begin to turn on their sides. Then, as fresh water is turned on and the trough fills, a slime will arise and float on top of the water, like a white scum. Coarse sand should be kept in the trough for the fish to rub themselves against. Salt is also good for the diseased gills and will free them from adhering sediment.

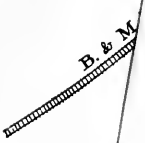
Fungus, "blue swelling," and other diseased conditions sometimes occur, but the most serious diseases of the fry are those just described. Parasites sometimes attack the fish, but if the water is pure and the fish in a healthy condition, they are not troublesome. To keep the fish

that are raised in troughs and tanks in a healthy state, it is well to give them a salt bath occasionally, and a small quantity of salt in their food will at times do them good. A little sediment from the reservoir, or such as collects on stones in the streams, is beneficial to fish if mixed with their food. It seems proper that they should have something of this nature, since all or nearly all of their natural food contains more or less sediment of the kind.

A very serious disease among adult rainbow trout shows the following symptoms: The afflicted fish refuse to take food, and very dark spots, from ¼ to 1 inch in diameter, appear on different parts of the body, varying in number from two or three up to twenty or thirty on each fish affected, a light spot about the size of a green pea appearing on the head immediately over the brain. The fish become restless and seek the shallow water in the corners of the pond, hiding among the plants, and begin to die within twenty-four hours from the time the disease is noticeable. They jump and dart around in the water in a frightened manner, settling back on their tails and sinking to the bottom of the pond in their last struggles. This disease made its appearance at Wytheville in December, 1895; it was first observed among a lot of 637 yearling Von Behr or brown trout that had been delivered at the station on November 29. The first sign of the disease was noted about the 5th of December, and by the 12th of the month 455 of the 637 fish were dead.

These fish were in the nursery during the first stages of the disease. The water in which they were held passed from them through an empty pond into a second one containing about 1,000 large rainbow trout that had recently been stripped of their spawn. On the morning of December 23 the disease made its appearance among the latter, and by 4 o'clock in the afternoon of the same day 56 of them had died. Salt was applied and the water in the pond was drawn down to about 300 gallons, and 150 pounds of common salt were sprinkled evenly through it. The fish were allowed to remain in this brine about 15 minutes, when they showed signs of weakening by turning on their sides; then fresh water was turned on freely. Good results were at once noticeable, the fish became quiet and appeared to rest more easily, and steadily improved, another application not being necessary. The final result was that 70 per cent of the adult rainbow trout that had been treated with salt were saved, while of the yearling brown trout that were not thus treated nearly 71½ per cent died.

Foul ponds cause disease, and if the fish become sick from this reason, they must be removed to a clean pond at once and given a salt-and-clay bath, which is applied as follows: While the salt bath, before described, is being given, 2 or 3 bushels of clay are placed in the reservoir or supply-trough, and when the fresh water is turned on after salting, the reservoir is flushed for 30 minutes with roily water from the clay, and after the latter is washed away an increased amount of fresh water is turned on for ten days or more.



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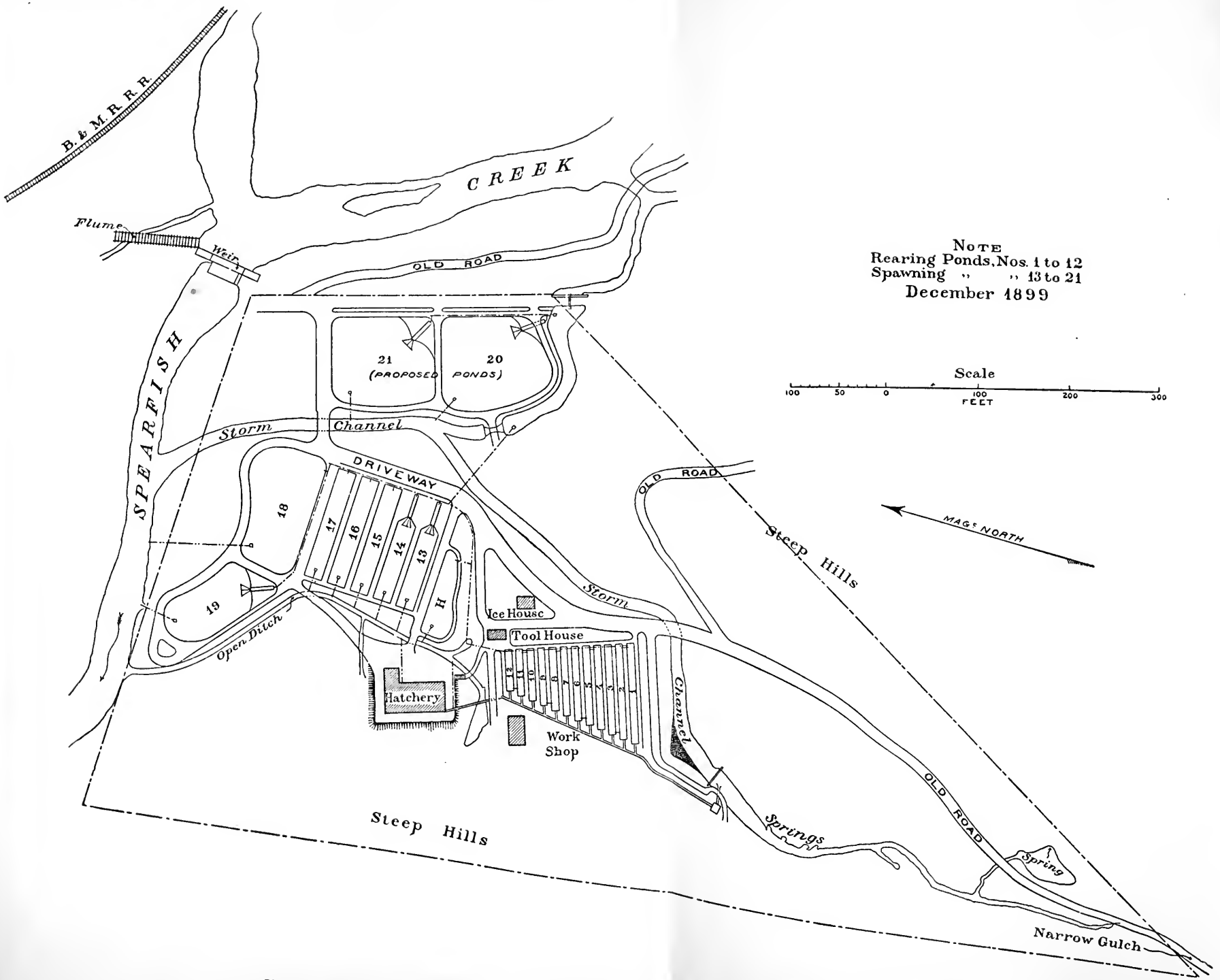


PLAN OF STATION AT SPEARFISH, SOUTH DAKOTA, SHOWING TYPICAL ARRANGEMENT OF TROUT PONDS.

Adult fish are very liable to be affected with fungus, which generally appears after a bruise or hurt, or when the fish are in an emaciated condition. If the trouble results from an injury, it can often be cured before it spreads to the sound flesh, but if fungus spreads like a slimy web all over the fish, it is fatal. Fish must be handled very carefully during the spawning season to prevent scarifying the body in any way, as they are especially susceptible to fungus at that period. Should it occur, the fish must be caught at once, rubbed with salt on the affected part, and then released in a pond or tank by itself, where it can be caught for further treatment in a day or two, while those affected all over the body should be killed and thrown out at once.

"Glassy eggs" may be the result of overretention of the eggs on the part of the parent fish. If the eggs are not delivered within a reasonable length of time, say from 36 to 48 hours after they fall from the ovaries into the abdomen, they are surrounded with a thin watery fluid, having a glassy appearance, which if allowed to come in contact with water will change to a milky white, and the eggs absorbing this fluid become hard and "glassy," after which fecundation is impossible. Many thousand eggs have been lost annually on this account, and many brood fish lost or rendered worthless from the same cause. The fish in captivity will not spawn of their own accord unless they have access to gravel or earth in which to make nests. If attention is not given to the spawning fish and their eggs taken when ripe, they soon become very dark in color, the abdomen swells, and sometimes the head will enlarge, causing the eyes to protrude. Under these conditions the fish will die in a few days, but with free and easy access to the raceway they will not often be thus affected.

THE BROOK TROUT.

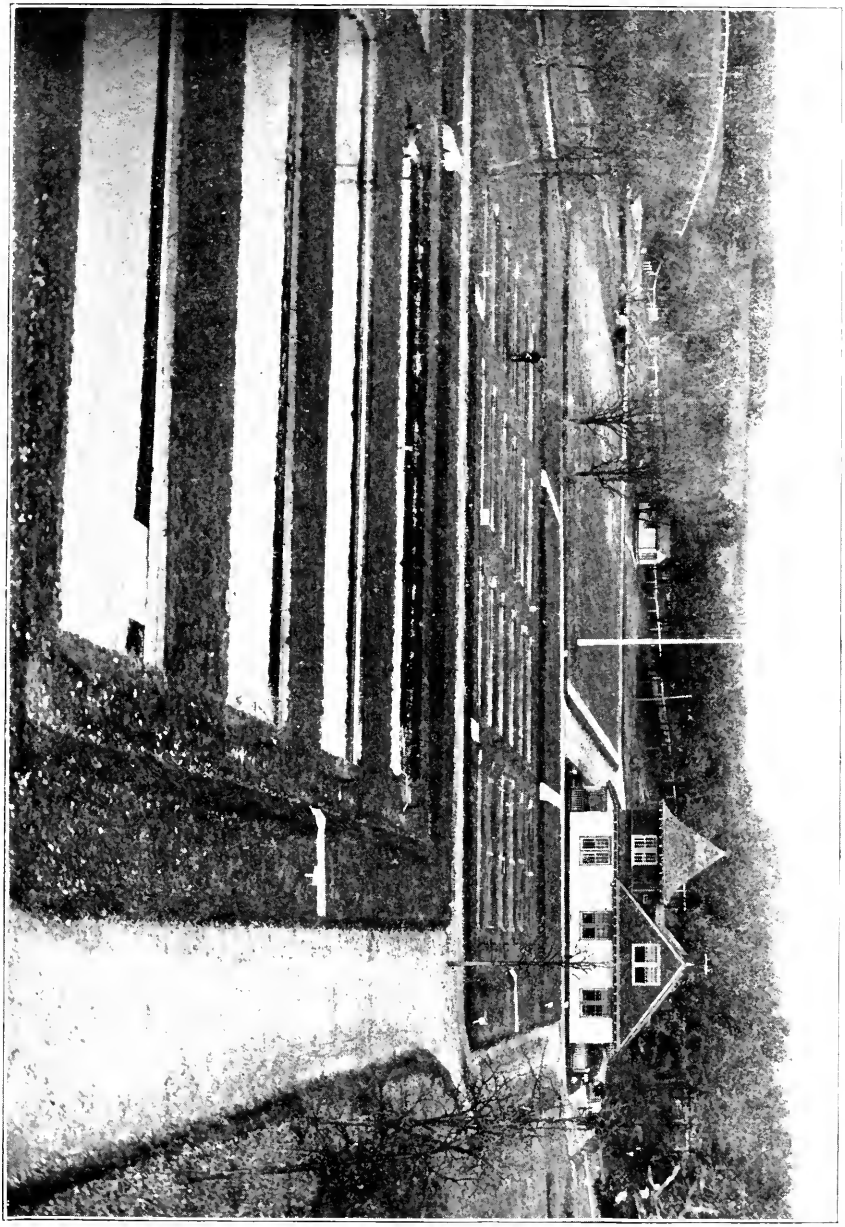
DESCRIPTION OF THE FISH.

The brook trout or speckled trout (*Salvelinus fontinalis*) is one of the most beautiful, active, and widely distributed of the American trouts. It prefers clear, cold, rapid streams, and belongs to that group of trout known as charrs, characterized by the presence of round crimson spots on the sides of the body. Other members of this class are the saibling or charr (*S. alpinus*) of Europe and Greenland; the Sunapee trout (*S. alpinus aureolus*), found in parts of New Hampshire and Maine; the blueback trout (*S. oquassa*) of the Rangeley Lakes in Maine, and Dolly Varden trout, red-spotted trout, or bull trout (*S. malma*) of the Pacific States and Alaska. The lake trout also belongs in this group.

The general form of the brook trout's body varies considerably, sometimes being elongated and sometimes rather short, but the usual depth is about one-fourth or one-fifth of the length. The head is large and blunt, and is contained $4\frac{1}{2}$ times in the body length. The large terminal mouth is provided with teeth on the jaws, tongue, and palate bones, and also with a small patch on the vomer. The eye is placed high in the head; its diameter is about one-sixth the length of head. The gillrakers on the first arch number about 17, of which 11 are on the lower arm. The scales are very small and numerous; about 230 are in the lengthwise series, and 35 above and 35 below the lateral line. The dorsal and anal rays are 10 and 9, respectively. The tail is square or slightly lunate in the adult, forked in the young.

There is considerable variation in the color of this trout, dependent on local conditions, sex, and age. The head, back, and sides of the body, dorsal and caudal fins are of a grayish or greenish color; the back, head, dorsal, and base of caudal are mottled with dark green or black. In the male there is a reddish band along side of belly. Along the middle of the side are numerous round light-red spots surrounded by whitish or light-brownish circular areas. The lower fins are dusky, with a pale or cream-color anterior border bounded by a black streak; remainder of fin often red in breeding males. The brook trout may be distinguished from the other charrs by the dark-brown or black marblings on the back and the general absence of spots on the back.

The parr-marks, which are always present in young trouts and salmons, are often found in large brook trout, and may even be permanent in aquarium or pond specimens and in wild fish with a restricted environment. These marks, which in the brook trout are about 8 in number, are large, dark, vertical blotches or bars extending along the sides. Persisting parr-marks are shown in the accompanying colored illustration of an artificially hatched and reared brook trout. (See frontispiece.)



HATCHERY AND REARING-PONDS FOR TROUT AT MANCHESTER, IOWA.

FOOD, SIZE, ETC.

The brook trout has a voracious appetite and takes advantage of every opportunity to satisfy it except in the spawning season, when it takes no food at all. It is strictly a carnivorous fish, its food consisting chiefly of crustacea, mollusca, and various forms of insects and worms. When pressed with hunger it does not hesitate to devour its own kind.

The size of these fish varies in different localities, usually in proportion to the abundance of natural food and to the size of the body of water in which they are found. They seldom, however, exceed 2 pounds. The Au Sable River trout will rarely run as large as 2½ to 3 pounds, but in other rivers of Michigan larger examples are occasionally found. In southern New York they seldom weigh over 2 pounds, while in the Rangeley Lakes, of Maine, they have been caught weighing 10 pounds. The rate of growth also varies with the surrounding conditions and is more rapid in water of higher temperature and with a plentiful supply of food. Under favorable circumstances an average growth for the first year is from ¾ to 1 ounce, in two years 8 to 10 ounces, in three years about 1 pound.

While not of any considerable commercial importance, the brook trout is highly esteemed as a table delicacy on account of the flavor and quality of its flesh, and, as it is very game, it is much sought after by sportsmen. Those from clear, swiftly flowing streams do not grow so large as those found in quiet and deeper waters, but are superior in quality and appearance.

RANGE, SPAWNING, ETC.

The natural range of the brook trout in the United States is from Maine to Georgia and westward through the Great Lakes region to Minnesota, and in Canada from Labrador to the Saskatchewan. Owing to its hardy nature and ability to adapt itself to new surroundings, it may be successfully transplanted into suitable streams, and has been extensively introduced into waters to which it was not native, in Michigan, Wisconsin, and Minnesota, many of the waters of the Rocky Mountains and the Pacific Coast, the Eastern States, and the creeks and rivers of the Alleghany range of mountains. With the possible exceptions of the rainbow trout and steelhead it is the hardiest member of the salmon family and will make a brave struggle for existence even with adverse surroundings. All streams can not be successfully stocked with this species; the temperature of the water must not be too high nor the flow too sluggish, although an unfavorable temperature is no serious obstacle if the speed of the current is great enough to insure a sufficient aeration of the water, or if there are creeks fed by springs flowing into the main stream to which the fish can run. The best streams are those with a gravelly bottom, clear shallow water, and a steady current, and waters to be stocked must contain a sufficient amount of natural food and suitable places for spawning.

The Michigan streams exemplify the practical results attained in the introduction of brook trout in new waters. The Au Sable River was long thought to be especially adapted for this species, but it abounded with grayling, and until this beautiful fish began to disappear no movement was made toward introducing the brook trout. The lumber interests of that section made it necessary to use the river for conveying logs to various points downstream, and, as the log-driving could be done only during the spring freshets, it came just at the time when the grayling were on their spawning-beds. They were driven away and the beds destroyed by the plowing of logs through the river bottom each year, till the fish gradually began to disappear. The brook trout was suggested as the proper substitute, because its spawning season is in the autumn when the river is undisturbed, and the Michigan Fish Commission began the work by planting 20,000 fry in the year 1885. Though additional plants were made from time to time, both by the Michigan and United States Commissions, no results were observed for some years, and it was thought that the work had been a failure. But the natural instinct of the fish had caused them to push from the main river into the small tributaries, where they multiplied and grew during these years till they finally crowded down into the river itself. Here they found as suitable a home as in the small streams, and their numbers gradually increased till now the stream is completely stocked.

In the autumn of 1895 a camp was established for the United States Fish Commission 9 miles below the village of Grayling for the purpose of taking spawn from wild fish. The work was confined to rod-and-line fishing until the spawning season opened, when it was found necessary to adopt some other plan, as at this time the trout refuse to feed. During the five weeks, in which the rod was used exclusively, 3,000 spawning fish were taken. A small seine was then used for capturing the fish, by hauling it at right angles to the current of the river, directly across the spawning-beds, which thickly dotted the river bottom in some places. By this method a tubful of trout at one haul was often taken, and during the period the fish were running between 8,000 and 10,000 were obtained. This illustrates the abundance in which this species is found in a river to which it has been transplanted. A conservative estimate would place the number of trout taken from this stream in the season of 1895 at 100,000, perhaps 25 per cent being rainbow trout. Other waters of the State have been successfully stocked, so that the northern half of lower Michigan now contains a network of trout streams, made by introducing this fish into waters where it was not indigenous.

In its native haunts, whether in lake or stream, the brook trout is usually found in the same clear, cold, spring water, and prefers brooks or streams flowing swiftly over gravelly bottoms. It pushes from the rivers into the small streams, seeking the headwaters, searching out

deep pools and eddies where it can lie concealed beneath the shelter of grassy banks or logs, and see without being seen. Under artificial conditions it endures greater temperature than in its native waters, where it is seldom found in water over 60° to 65°. It thrives at much higher temperature in swift, well-aerated streams than in sluggish waters.

The brook trout spawns in autumn during the falling of the water temperature. The season, which usually lasts about two months, begins earlier in northern latitudes, in the Lake Superior region in September or even August, while in New York, New England, and lower Michigan it commences about the middle of October.

As the spawning time approaches the fish push up toward the shallower waters where the female selects a spot near the bank of the stream and prepares her nest by washing out the sand with her tail and pushing aside the gravel with her nose. After forming a slightly concave depression she deposits a part of her eggs on the newly cleansed gravel, and the male—which up to this time has been playfully swimming around the nest—emits milt upon them almost simultaneously. The female then covers the eggs with loose gravel. The spawning, impregnating, and covering are repeated continuously until the eggs are all laid. After the spawning-ground is once selected it is hard to drive the fish away, the female especially returning to the same spot at the earliest opportunity. A female has been taken from her nest and marked and then returned to the water a mile down the stream, and the next morning was again found on the same bed.

The eggs vary in size, but are usually one-sixth of an inch in diameter. The number yielded by one fish depends on its size and age, yearlings usually producing from 150 to 250, two-year-olds 350 to 500, and older fish 500 to 2,500. The time necessary for developing the eggs is dependent on the temperature of the water, varying from about 125 days in water at 37° F. to about 50 days in water at 50° F.

TROUT-CULTURE IN AMERICA.

The first attempt at artificial trout-culture in America was made in Ohio in 1853 with marked success. Further satisfactory trials were made in 1855 and 1859 in Connecticut and New York, and in 1864 a hatchery was established in New York which carried on the work on a large scale. Somewhat later the work was taken up by the State and United States governments and is now very extensively conducted in all parts of the country. The methods described in the following pages are those which have been found advantageous at the Northville Station and are there pursued.

SPAWN-TAKING.

Eggs are obtained from brood-fish held in ponds and from wild fish obtained at a field station located on a tributary of the Au Sable River near its junction with the river. As the spawning season approaches, the brood-fish at the station are sorted according to age and size and transferred to spawning-ponds, which are seined once a

week for ripe fish in the early part of the season and later on three or four times a week. Great care is used in manipulating the seine, and when its ends are drawn up on the bank the fish are transferred with dip-nets from the bag of the seine into tubs, care being taken not to overcrowd the tubs. The fish are then examined; those which are not ready are returned to the pond, while the ripe males and females are placed in separate tubs or buckets. A good spawn-taker can tell at a glance if a female is ripe, and only in such condition should an attempt be made to take her eggs. As soon as these fish have been stripped and the eggs fertilized, the spent fish are liberated in a separate pond to avoid rehandling them during the season.

After the males and females are separated, an ordinary milk-pan coated with asphaltum paint on the inside, to prevent rust, is dipped in water and allowed to drain, leaving only the water that clings to the inside. Taking a female from the tub, the spawn-taker holds her as quietly as possible till all struggles cease, and then pressing gently with the thumb and forefinger a little above the ventral fins, passes his hand down the belly to the oviduct, repeating the operation till all the eggs are extruded. The eggs are immediately impregnated with milt, obtained from the male in a similar manner, except that more force is necessary and the pressure is made at a point about midway between the ventral and anal fins.

The contents of the pan are next lightly stirred with a feather to insure impregnation of all the eggs possible. They now present a milky appearance and are washed in as many changes of water as is necessary to thoroughly cleanse them from milt and refuse, when the pan, half-filled with fresh water, is placed in running water to keep the eggs at a low temperature. In 30 to 60 minutes, according to the temperature of the water, the separation of the eggs ensues.

THE HATCHING APPARATUS.

The apparatus at Northville is arranged as follows: A tank 15 feet long, with a partition running its entire length, is so placed that its lower end rests upon the upper end of a similar one 13 feet long, which differs from the upper one only in that it contains two boxes less. Nine partitions, placed crosswise of the tank, form, with the lengthwise partitions, a double row of eight compartments, each of which is 19½ inches long and 15½ inches wide, and is provided with a waste-water channel or sluiceway leading into the next compartment. In these compartments are placed Clark hatching-boxes.

The Clark box is 18 inches long, 14 inches wide, and 9½ inches deep, and is made from ¾-inch dressed whitewood lumber. On its under side the box is provided with feet, 1½ inches square and ⅜ inch thick, to allow a free circulation of water under it and to prevent it from resting upon any sediment or refuse that may be deposited on the bottom of the tank; and on the inside in each bottom corner is fastened a block, ⅜ inch thick by 1½ inches square, to support the trays. Five circular openings, ⅞ inch in diameter, permit the escape of water from the box. A slot is

SELECTING AND STRIPPING RIPE TROUT, NORTHVILLE, MICH.

cut in one end of the box so that water from the compartment above can not flow into the one below without falling into and passing through this box. Upon the feet or risers inside the box rest 9 trays, placed one upon the other, the end of the box which contains the slot fitting snugly against the upper end of the compartment, in which is fitted a tin overflow. The whole is held in place by a crossbar or binder, which fits in $\frac{3}{8}$-inch grooves cut in both sides of the tank. The binder, resting on the box, keeps it from rising in the water, and is provided with feet so placed as to prevent the trays from floating in the box itself. The trays are perforated zinc or fine wire netting, tacked on a frame 16 inches long and 7 inches wide inside measurement, made from $\frac{3}{4}$-inch pine $1\frac{1}{4}$ inches wide.

CARE OF THE EGGS.

The eggs after separating are placed in troughs, the bottoms of which are covered with half an inch of gravel, and here they remain till the eye-spots begin to appear.* During this interval of about 30 days the principal care consists in sorting out bad eggs, and, with a feather, gently changing the position of good ones to prevent sediment from collecting on them. At the expiration of this period they are ready for transfer to the hatching-boxes. They are drawn off the gravel by means of a siphon into a tub or bucket which has been half filled with water to preserve them from injury and then carefully dipped into a glass graduate, measured, and placed on the hatching-trays. The trays are arranged in the boxes in stacks of nine, and 5,000 eggs are allowed to each tray except the top one, which is left empty and serves only as a cover. The eggs from domesticated brook trout measure 350 to 450 per fluid ounce, depending on the age of the fish. Eggs from wild trout collected in the Au Sable River measure 450 to the fluid ounce.

At intervals of from 3 to 6 days during the period of incubation, in order to remove the bad eggs, the trays are taken from the boxes and placed in a shallow picking-trough through which a stream of not more than 3 gallons per minute is flowing. This trough is only wide enough to allow perfect freedom in handling the trays when putting them into or removing them from it, and only of sufficient depth to allow the eggs to be fairly covered. Nailed to the bottom on each side is a $\frac{1}{2}$-inch strip, $1\frac{1}{2}$ inches wide, and running the entire length of the trough. These strips permit the free passage of water beneath the trays, as otherwise the water would flow over the tops and a great many eggs would be lost. The bad eggs are removed with tweezers, the labor being usually performed by girls, who become so expert that one girl will often remove 100 bad eggs per minute.

After the incubation has reached a stage where the fish are beginning to break their shells, the hatching-box is taken out and reversed,

*The practice of holding the new eggs on gravel until the eye-spots begin to appear is pursued at Northville with eminent success, but at the other trout hatcheries of the Commission, where equally good results are obtained, it is customary to transfer the eggs to the hatching-trays as soon as they are impregnated, as is described in the chapter on the rainbow trout.

the open end being fixed snugly against the lower wall of the compartment. The closed end of the box being thus placed upstream, the water is prevented from entering except through its former exit, the holes in the bottom of the box, and is thus forced up through the box, with an exit at the top which prevents the sacs of the hatching fish from being forced, by pressure from above, down through the screen, as would be the case if the box were left in its former position.

When the process of hatching is nearly completed the trays are removed and emptied into a large pan filled with water, where the dead shells and other refuse, being of low specific gravity, rise to the top and can be easily poured off. This is called washing the fish. The fish are then replaced upon the trays and returned to the hatching-boxes, where they remain until the food-sac is nearly absorbed, a period of from 25 to 40 days, according as the temperature varies from 50° to 38° F.

The young fry, deprived of their food supply by the absorption of this sac, must soon be placed where they can get their sustenance elsewhere. They may be planted in waters suitable to their nature, or reared for breeding or other purposes at the station.

THE FIELD STATION.

The egg-collecting station previously referred to is on a tributary of the Au Sable, flowing about 1,000 gallons per minute. A dam is thrown across the stream and 100 feet above is a screen to prevent the fish from escaping in that direction. The dam is simply constructed by banking up mud, sand, and turf, and has a frame sluiceway 3 feet long, 2 feet wide, and 2 feet deep. In the sluiceway is inserted a double screen of ¼-inch mesh wire netting, two screens being necessary to keep the overflow clear and reduce as low as possible any loss of fish through this outlet. The inclosure accommodates about 10,000 fish. Fish are obtained with rod and line, until they begin to run from the deep pools upon the spawning-grounds, when much better results are obtained with nets. With an ordinary seine at the approach of the spawning season, the fish can be taken in large numbers from their spawning-beds. As the season advances and too many fish are caught that have already spawned, operations are suspended.

As soon as ripe fish are found among those caught on the spawning-beds, the inclosure is hauled with a seine and the fish are looked over twice a week until the eggs are taken. When the season is fairly open the spawn may be taken from most of the fish immediately after they are caught, thus obviating the difficulty of transferring them from the point of capture to the inclosure, in some cases a distance of 3 or 4 miles.

For holding the eggs two pairs of troughs are placed on standards driven into the bed of the stream, with a passage between them wide enough to admit a man. The water is received through two 1-inch orifices in a bulkhead about 9 feet long, situated at the head of these troughs and fed by a roughly constructed raceway leading from a small spring about 6 rods distant on the hillside. The water from each of the

INTERIOR VIEW OF NORTHVILLE HATCHERY: CLARK BOXES IN FOREGROUND; CLARK-WILLIAMSON BOXES IN BACKGROUND; GIRLS PICKING EGGS AT THE RIGHT.

openings feeds two troughs, so placed that the lower end of the upper one rests upon the head of the other, thus creating a fall of nearly the height of the troughs. Each trough is 14 feet long, 5 inches deep, and consists of a double row of boxes, each box 17 inches long, 15 inches broad, and 2 inches deep, giving a capacity of from 8,000 to 10,000 eggs.

SHIPPING GREEN EGGS.

Green eggs can be safely moved at any time up to and including the eighth day. They are shipped from the field station to the hatchery in cubical boxes constructed from ½-inch pine lumber, just large enough to admit, with a surrounding air space of ½-inch, 19 canton-flannel trays, 18 inches square on the inside, the frames of which are made from ⅞-inch square white pine. The eggs are siphoned from the gravel boxes, as described above, and, using a graduated dipper for the purpose of ascertaining approximately the number of eggs necessary to make them about two deep on the tray, the packer pours them upon the flannel and spreads them as evenly as possible with a feather. The tray is then placed in the box and the operation repeated until eighteen trays are filled with eggs. The nineteenth, or top tray, is usually left empty, but if the weather is very warm it is filled with fine ice. The cover is then fastened down, the box marked, and the eggs are ready for shipment to the hatchery.

PLANTING THE FRY.

In their natural state, as soon as the weight of the food-sac has diminished by absorption enough to permit their rising, the fish begin to take food, and by the time the sac is entirely gone they are probably taking it regularly. When very young fry are transferred to outside waters where there is natural food only, it should be done 8 or 10 days before the sac is entirely absorbed, for, if delayed till after the sac disappears, many will die before they become accustomed to finding food in their new home.

Brook-trout fry are usually transported in ordinary round-shouldered cans of 10 gallons capacity, the number of fish per can depending entirely upon the distance they are to be carried and the facilities for taking care of them en route, such as opportunities for changing the water, supplying fresh ice, etc. For a short trip of from 5 to 10 hours duration, between 4,000 and 5,000 are carried in each can, but where they are to be on the road from 1 to 5 days, it is hardly safe to attempt carrying more than 2,500. The Commission distributes fry by means of its cars, built especially for the purpose, in which either running water is kept upon them or fresh air introduced into the water to make it life-sustaining. Small shipments are made by a special messenger in a baggage car, the railway companies usually offering every available opportunity for changing water, etc. The fish, upon arrival at the railway point nearest their destination, are carried thence by wagon to the stream where they are to be planted, by distributing them in small lots in different places where there is shallow water and a good bottom.

REARING AND FEEDING.

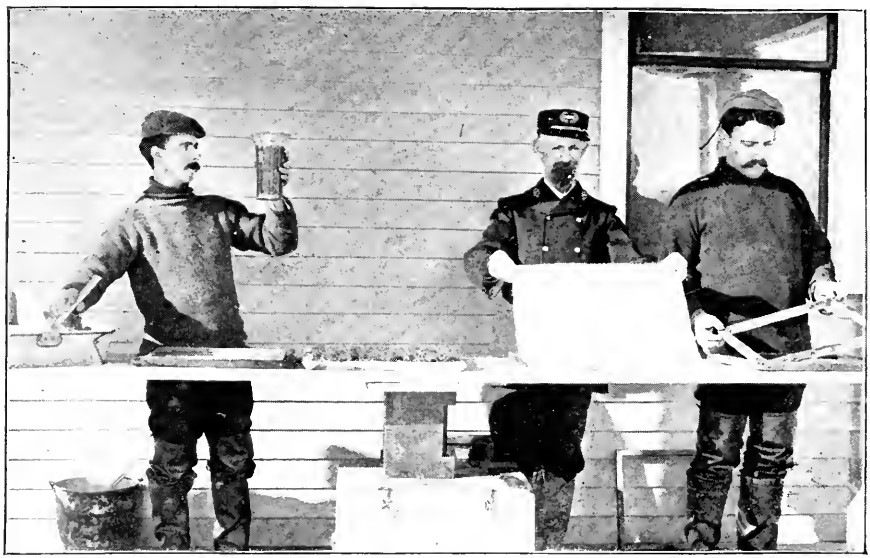
If the fry are to be reared for breeding, one week before the food-sac is absorbed they are changed from the trays to a large pan and removed to the rearing-troughs. Gravel should not be used in these troughs, as the unconsumed food works down into it and, becoming fungussed there, causes a greater spread of disease and increases the labor of caring for the fish.

The time to begin feeding the fry is readily ascertained by trial. If they rise to minute particles of food thrown upon the water, they are then ready for regular feeding. The time and frequency of feeding young fish, the kind of food, and the manner of feeding them, are of the greatest importance. Liver gives better results than any artificial food, and its preparation is very simple. Beef livers are ground by a meat-chopper and then strained through a fine-meshed screen, a thick pudding being made by the addition of water. A small portion, only such an amount as the fish will readily eat at a time, is spread upon the surface of the water with a feather, and they are fed as often as six or eight times per day until they become used to the new diet. As they grow older the quantity of food may be increased but the fish are fed less frequently. At this stage the young fish have such a precarious hold upon life that too much attention can not be given to their care. Not more than 20,000 can be held with success in a feeding or rearing trough, and a regular stated supply of water is kept flowing through to prevent disease, and the fish are properly thinned out in order to prevent loss by suffocation when they increase in size. About 30 gallons of water per minute are sufficient for 20,000 fry, though this quantity is increased as the fish grow stronger and are able to breast a heavier current.

In the spring season, when the water begins to grow warm, the fish require more room than the feeding-troughs afford, and it is then necessary to transfer them to ponds. The Northville rearing-ponds are 5 feet by 20 feet, made from 2-inch pine boards and provided with a gravel bottom. A pond of this size accommodates from 10,000 to 20,000 fry till the middle of the summer, when the number is reduced to as low as 5,000. It is advisable to place not more than 5,000 in the pond at first to avoid the labor of reducing the number of fish at different times, and also because crowding into too small a space retards their growth.

At first the fish require coaxing to induce them to eat, as the change to their new abode has frightened them, and a great deal of patience is necessary in their treatment. They are fed at regular intervals three times per day. As their appetites are poor for the first few days, the liver will fall to the bottom and foul the pond, if great care is not exercised, and three fourths of an hour is not too long for feeding 5,000 fry. The time occupied in feeding is diminished and the amount of food increased according to the judgment of the fish-culturist; but their appetites should never be completely satisfied.

REMOVING GREEN EGGS FROM SHIPPING-TRAYS NORTHVILLE.



PACKING EYED EGGS NORTHVILLE.

By early winter they will have grown to a length of from 3 to 6 inches, necessitating a change to a larger pond. The Northville breeding-ponds are 20 by 75 feet, and are constructed in the same manner as the rearing-ponds. One of these larger ponds accommodates 10,000 yearlings, 5,000 two-year-olds, and about 3,000 fish from three to five years old. By the time the fish are three years old and over, less care is required in the preparation of their food, as the liver may be given to them in pieces half an inch in diameter.

PACKING EYED EGGS FOR SHIPMENT.

Eyed eggs prepared for shipment in the following manner have been sent from Northville to all parts of the United States with practically no loss: The trays upon which the eggs are to be shipped are made from the same materials as those upon which green eggs are carried, but are usually much smaller. Fewer eggs are placed upon a given surface than is the case with green eggs. For example, 10 trays, 12 inches by 12 inches, will carry 50,000 eggs; 8 trays, 10 inches by 10 inches, 32,000 eggs; and 5 trays, 8 inches by 8 inches, 12,500 eggs; or 5,000, 4,000, and 2,500 eggs per tray, respectively.

The trays are allowed to stand in cold water till thoroughly soaked, and are then drained off and taken to the packing-room. After the dead eggs have been removed from a box, the trays are taken out, drained, and removed to the packing-room. A $\frac{3}{4}$-inch wooden frame, made to fit the inside of the canton-flannel tray, is then inserted, the eggs are carefully brushed with a feather from the wire trays and spread as evenly as possible upon the flannel. The eggs have been previously measured at the time when they were removed from the gravel to the hatching-box, so the number to be placed upon each tray can be easily determined. After the eggs are spread upon the flannel, the inside wooden frame is taken out, leaving a $\frac{3}{4}$ inch margin around the inside of the tray. A square of mosquito netting large enough to lap over on all sides of the tray is laid upon the eggs and tucked down firmly along the inside. Sphagnum moss is scattered to a depth of about $\frac{3}{4}$ inch upon this netting. The moss is prepared by removing sticks and other foreign matter; it is soaked in water a short time and then run through a clothes-wringer. In spreading it upon the netting the moss is picked apart and made as light and fluffy as possible, to give the eggs plenty of oxygen.

When the required number of flannel trays are packed they are placed one upon another and cleated together on all sides, with boards at the bottom and top. This crate is usually placed, if possible, where the temperature of the air is below freezing, so that the moss may be slightly frosted before the crate is put in the shipping-case.

A case is made large enough to allow a 4-inch space above, below, and around all sides of the crate when it is placed in position. Its bottom is filled with fine shavings, 4 inches deep, and the crate placed upon them as nearly as possible in the center of the case. Shavings

are packed tightly around the crate, a few being thrown in and pounded down securely before more are added. This must be well done, as the shavings are the only means of preventing a change in the position of the crate. The top of the crate is then covered with closely packed shavings and the cover of the case screwed on. By means of rope or iron handles the case may now be moved about with ease, and is ready for shipment.

REFRIGERATOR BOX FOR SHIPMENTS ABROAD.

A double box is used for this purpose. The inside one is 2½ inches larger on all sides than the crate of trays, and the outside one large enough to make a 5-inch space on all sides when the smaller box is placed within it. The trays of eggs are prepared as in ordinary shipments, and when crated are placed in the smaller box upon a frame which is constructed from a ⅛-inch strip, 2½ inches wide, tacked at right angles to the inside and bottom of this box. In the chamber thus formed between the crate and the box is packed finely chopped ice, an exit for the water resulting from its melting being provided by a half dozen openings in the bottom of the box. This box is now packed according to the same plan as that followed with the shipments for a short distance. Where there is an opportunity, it is well to have the case unpacked en route and new ice added.

Eggs have been sent in this manner to England, Mexico, New Zealand, Japan, and South America.

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